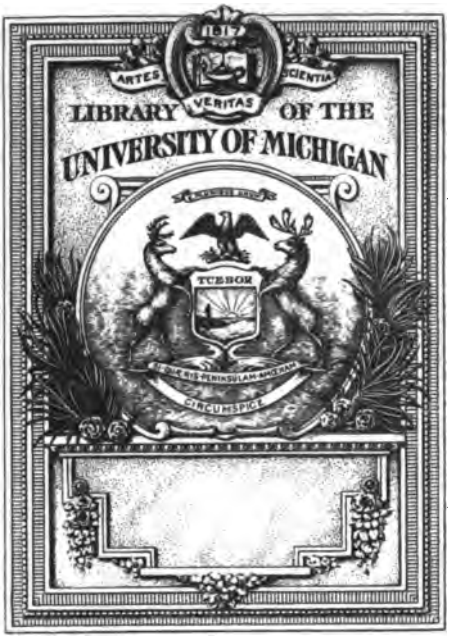

The University of Minnesota

STUDIES IN ~~PUBLIC HEALTH~~ the biological sciences NUMBER 1

A STUDY ON THE SPREAD OF TUBERCULOSIS IN FAMILIES

BY

HERBERT G. LAMPSON

MINNEAPOLIS
Bulletin of the University of Minnesota
December 1913

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A STUDY ON THE SPREAD OF TUBERCULOSIS IN FAMILIES

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This investigation was carried on under a grant made by the Antituberculosis Committee of the Associated Charities of Minneapolis, Minnesota. The plan of work was determined upon, and the investigation supervised, by a special Committee on Spread of Infection. George Douglas Head, M.D., Associate Professor of Medicine, University of Minnesota, Chairman.

A STUDY ON THE SPREAD OF TUBERCULOSIS IN FAMILIES

The special problem to be investigated in this study can be stated as follows:

Given a known case of active tuberculosis in a family, what proportion of the individuals in that family show evidence of an infection with tuberculosis?

The plan of investigation was outlined as follows:

1st. Select a given number of families in each of which a case of pulmonary tuberculosis existed at the time of the investigation and which had been living for at least a year prior to the investigation in the home of each of these families.

2d. Prove the case to be one of tuberculosis by the finding of tubercle bacilli in the sputum or other excreta.

3d. Make a careful scientific study of all the individuals in these families and determine which of them show evidence of tuberculous infection.

4th. Make a similar study in a given number of families in which no persons with tuberculosis had been found, and compare these findings with the findings in the tuberculous families.

Material for the investigation was procured from three sources: (1) cases under the care of the visiting nurses of the Associated Charities of Minneapolis; (2) cases under the care of the Health Department of the City of Minneapolis; and (3) cases under private care.

Method of procedure and technique.—When a suitable case for study was found, it was first proved to be tuberculous by the demonstration of the presence of tubercle bacilli in the sputum. This was called the "center case," and so designated in the charts. All the individuals in the house directly exposed were examined and the name, address, date, age, sex, weight, height, nationality, occupation, social condition, general appearance, school attended, nutrition, and exposure (source and time of), were noted on the case card and a record kept.

The examination was made under the following heads: conformation of thorax, glands, bones and joints, skin, throat, lungs, other lesions, sputum, pulse, temperature, and respiration. In addition to the physical examination, tuberculin tests were made in all cases.

The Moro test, consisting of rubbing into the skin over the lower part of the sternum an ointment containing Koch's original tuberculin,

while frequently used, was not used alone, and was not relied on as demonstrating tuberculous infection. The results of the Moro tests have been disregarded in this report.

The Von Pirquet test, which consists of making three scarifications about one inch apart on the skin of the arm and applying to two of them Koch's original tuberculin, leaving the center one as a control, was used in all cases.

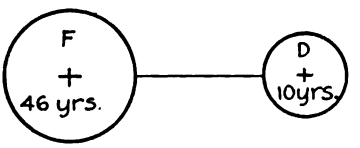
The Subcutaneous test, which consists of injecting subcutaneously Koch's original tuberculin, was used where possible. On account of the character of the material used in the study it was impracticable to use this test in as many cases as was at first planned on account of the difficulty of persuading people to submit themselves to this test.

The cases in which the Moro and Von Pirquet tests were used were all inspected after the lapse of forty-eight hours. A positive reaction to the Moro test is a diffuse redness of the skin with discrete papulation over the area to which the innunction is applied and the time of appearance is from twenty-four to forty-eight hours after its application. A positive reaction to the Von Pirquet test is a conspicuous redness about the points to which the tuberculin is applied, together with slight thickening, and possibly papulation, of the skin in the same area. The extent and brilliance of these reactions vary with the character of the case, but any conspicuous redness with swelling, with or without papulation, is classed as a positive reaction. A positive reaction to the subcutaneous test is the occurrence of a rise in temperature, other causes being eliminated, and a feeling of malaise, headache, backache, etc., during the first or second twenty-four-hour period following the injection.

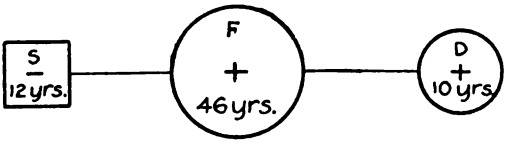
A positive case of tuberculosis taken as the center case is indicated in the group diagrams by the large heavy circle, with initial, age, and + sign. Thus,

= father, positive, age 46 years.

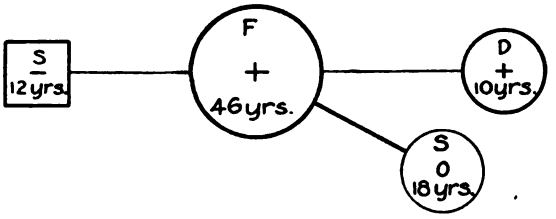
The other positive cases of the group are indicated by smaller heavy circles enclosing relationship initial, + sign, and age, and are connected with the center case circle with a light line. Thus,



The negative cases of the group, or those showing no evidence of infection, are indicated by a square containing the relationship initial, — sign, and age, and connected with the center case circle by a light line. Thus,



The members of the group not seen are indicated by a small lighter circle containing the relationship initial, 0 sign, and age, and are connected to the center case circle by a heavy line. Thus,



The letters used are: H = husband, W = wife, F = father, M = mother, S = son, D = daughter, etc., and indicate the relationship of the individual to the center case.

Some of the group cards have for the center case individuals who were dead at the time of the investigation. These were all undoubted cases of tuberculosis. All others classed as positive center cases were proved open cases by the finding of tubercle bacilli in the sputum.

In addition to the ten non-tuberculous families found during the investigation, all of whom were under observation as tuberculous families or suspects, five other non-tuberculous families were selected and subjected to the same examination and tests as the tuberculous families and were used as controls.

For convenience the groups are reported in alphabetical order rather than in the order in which the work was done. The first thirty-three center cases described are classed as open cases, as in all of them tubercle bacilli were demonstrated in the sputum or the center case was dead of tuberculosis.

Simeon, A., 11th Avenue South. December 18, 1911.

Far-advanced case of pulmonary tuberculosis. Tubercle bacilli present in sputum in great numbers. Was taken sick two years ago with pleurisy

and was told that he had an abscess of the lung. No tubercle bacilli were demonstrated in the sputum at that time. Six months after the onset of disease he left home and lived for nearly a year in Arizona. After three months in Arizona tubercle bacilli were found in his sputum. He returned home nine months ago to die and on his return the first history of a definite exposure can be traced to his family.

Mrs. Ida A., his wife, a large, strong looking woman, with well-formed chest; has no sign of tuberculous infection except a positive Von Pirquet test. On account of her husband's sickness she was not willing to undergo further tuberculin tests.

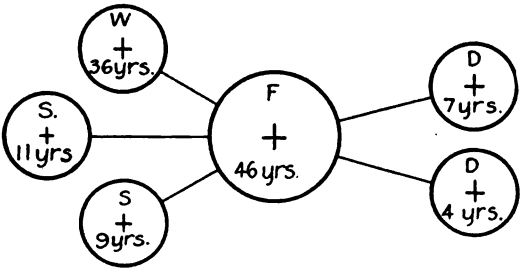
Ellsworth A., son, 11 years, shows several enlarged cervical glands, poor expansion of the chest, pulse 92, temperature 99.8, and gives a positive reaction to the Von Pirquet test.

Harold A., son, 9 years, large and well-developed; shows several enlarged cervical glands, pulse 98, temperature 100, and gives a positive reaction to the Von Pirquet test.

Ruth A., daughter, 7 years, large for her age but with rather poorly formed chest; shows enlarged tonsils, pulse 90, temperature 98.8, with positive reaction to the Von Pirquet test.

Ethel A., daughter, 4 years, of average size, well-nourished, with well-formed chest; shows several enlarged cervical glands, pulse 90, temperature 99.2, and positive reaction to the Von Pirquet test.

Three of the children were away from home for three months and one for five months during the time the father was at home.



In this family are five individuals showing evidence of tuberculous infection.

Peter A., Mill Street. January 13, 1912.

This patient was in the tuberculosis ward at the Minneapolis City Hospital in an advanced stage of pulmonary tuberculosis. He had lived at home nine months after tubercle bacilli had been found in his sputum at the University Free Dispensary.

This house is small, dark, unventilated, but clean.

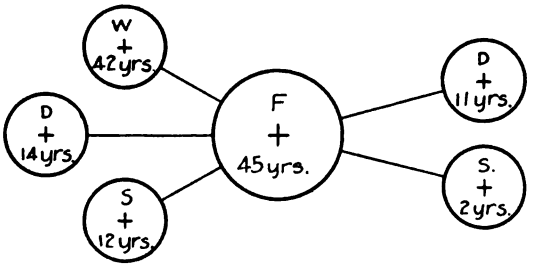
Catherine A., wife, 42 years, a good-sized, robust woman; shows no sign of tuberculous infection except a positive Von Pirquet reaction. A subcutaneous tuberculin test was not permitted in this case.

Anna A., daughter, 14 years, small for her age, well-nourished, with broad, short but stooped chest; shows dullness over right upper and middle lobes posteriorly, fine rales in same area; pulse 96, temperature 99.8, respiration 26, and a positive Von Pirquet reaction. She was sent to the Out-Patient Department of the University Hospital.

John A., stepson, 12 years, large for his age, very well-built and well-nourished; shows three enlarged cervical glands, pulse 84, temperature 100, and a positive Von Pirquet reaction.

Mabel A., daughter, 11 years, small, well-nourished, with well-formed chest; shows two enlarged cervical glands, pulse 84, temperature 99.1, and a positive Von Pirquet reaction.

Jimmy A., son, 2 years, large, well-nourished, well-built; has one enlarged cervical gland, pulse 120, temperature 99; shows a positive Von Pirquet reaction.



There is evidence of tuberculous infection in each member of this family of five.

Isaac A., 4th Street South. December 21, 1910.

A patient in the Thomas Tuberculosis Hospital. He was removed from his home to the hospital within one month from the time tubercle bacilli were found in his sputum. He is 28 years old, tall, slender, fairly well-nourished, with long, narrow, round chest. Shows signs of pulmonary tuberculosis in small areas in both lungs and has tubercle bacilli in his sputum. First examination of family was made three months after tubercle bacilli were found in sputum. Second examination made six months later.

House conditions: family living in two small, unventilated, untidy rooms. Diet fairly nourishing. Husband used sputum cup after diagnosis was made up to the time he left home.

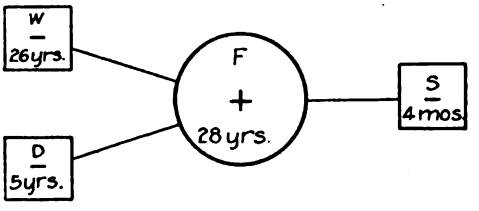
Mary A., wife, 26 years, strong, well-nourished woman; shows no evi-

dence of tuberculous infection; Von Pirquet test negative. Six months later Von Pirquet test again negative.

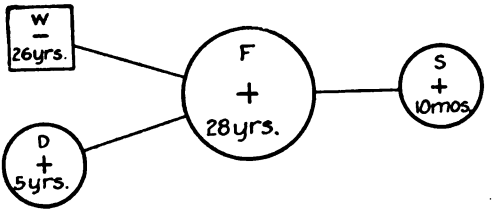
Anna A., daughter, 5 years, of average size, well-nourished; shows no signs of tuberculous infection; negative to Von Pirquet test. Six months later shows positive reaction to Von Pirquet test.

Earl A., son, 4 months, large, very well-nourished baby; shows no signs of tuberculous infection, and is negative to the Von Pirquet test. Six months later gives a positive reaction to the Von Pirquet test.

First Examination



Second Examination



In this family of four, three showed no evidence of tuberculous infection two months after first known exposure. Six months later two of these three showed evidence of tuberculous infection without further direct exposure.

Mrs. B., 21st Avenue South. December 9, 1911.

House conditions, four small, dark, dirty rooms, no ventilation. The woman died in this house after a sickness of over one year, about one month prior to this examination, of tuberculosis of the lungs.

Father was not examined.

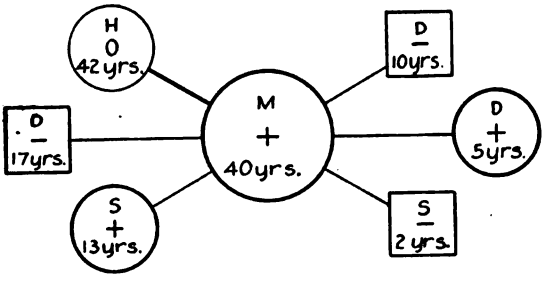
Theresa B., daughter, 17 years, small, well-nourished; shows no signs of tuberculous infection and is negative to the Von Pirquet test.

John B., son, 13 years, small, fairly well-nourished; with few enlarged cervical glands and enlarged tonsils; has had recent attack of tonsilitis; no signs of pulmonary tuberculosis, but has signs of active pleuritis with effusion; pulse 90, temperature 99, respiration 26, positive reaction to the Von Pirquet test.

Ruth B., daughter, 10 years, tall, slender, fairly well-nourished, with poorly shaped chest; shows no evidence of tuberculous infection; Von Pirquet test negative.

Josephine B., daughter, 5 years, short, fat, with well-formed chest, four enlarged cervical glands, enlarged tonsils, cogwheel respiration in lower left lobe posteriorly, pulse 90, temperature 99.4; reaction to Von Pirquet test positive.

Harold B., son, 2 years, well-developed and well-nourished; has several enlarged cervical glands; pulse 120, temperature 100.2, respiration 30; Von Pirquet test negative; has had whooping cough for two months.



In this family of five children were two who present evidences of infection with tuberculosis.

Mrs. A., 7th Street South. February 11, 1911.

The center case in this group is a maternal aunt who lived a year in the household and died there at the end of that time of pulmonary tuberculosis. The house was fumigated by the Health Department after her death, but had not been repainted or papered at the time of my last visit. The rooms are dark, unventilated, and overfurnished. The diet is wholesome. No sputum precautions were taken.

One sister and two brothers-in-law were not seen.

Marie, sister, 36 years, shows rales and increased fremitus in right middle lobe and gives a positive reaction to the Von Pirquet test.

Arthur, nephew, 11 years, undersized, poorly nourished; has a poorly shaped chest and enlarged cervical glands; gives a positive reaction to the Von Pirquet test.

Arne, nephew, 9 years, has a poorly shaped chest, enlarged cervical glands and tonsils, and shows distant breathing and pain in right base and altered voice in left base; gives a positive reaction to the Von Pirquet test.

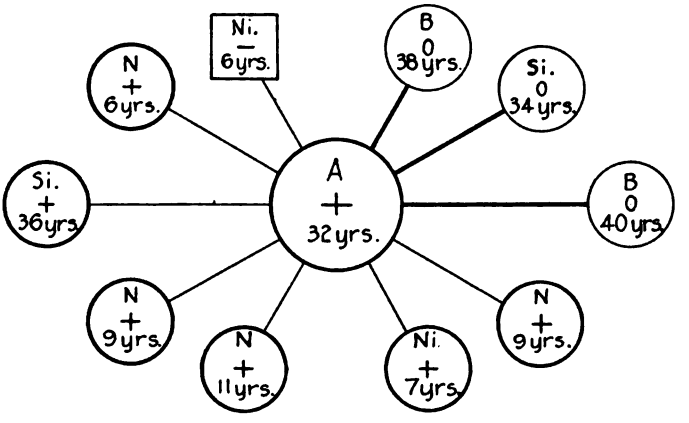
Fred, nephew, 9 years, tall and slender, poorly nourished, with poor general appearance, long narrow chest, and enlarged cervical glands; gives a positive reaction to the Von Pirquet test.

Myrtle, niece, 7 years, of average size, fairly well-nourished; shows rales, dullness, and increased vocal fremitus in left base; has some enlarged cervical glands, pulse 96, temperature 99.4, and gives a positive reaction to the Von Pirquet test.

Ingolf, nephew, 6 years, has had hemorrhages from the lungs and is reported by the City Health Department to have had tubercle bacilli in his sputum, though at the time of this examination he appeared to have little or no physical signs of disease but gives a positive reaction to the Von Pirquet test.

There was another niece, a girl in this family, who was negative to the Von Pirquet test, but the rest of whose record is lost.

Ingolf and Arne lived with their parents next door to the house in which the maternal aunt died. Their father and mother doing day work, these two boys spent most of their time playing with cousins in the house infected by the aunt and are therefore included in this family group.



Of ten people in these two families, seven were examined and six of these showed evidence of infection with tuberculosis.

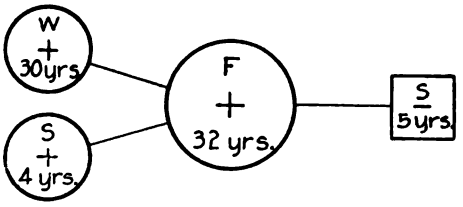
F. J., East 17th Street. January 26, 1911.

This was a far-advanced case of bilateral pulmonary tuberculosis of sixteen months' duration, with large numbers of tubercle bacilli in the sputum. The family was living in a fairly comfortable flat which could not be properly ventilated.

Emma J., wife, 30 years, was not examined, but submitted to the Von Pirquet test, which was positive.

Lloyd J., son, 5 years, of average size, well-developed, and well-nourished; with some slight cervical glandular enlargement; Von Pirquet test negative.

Gerald J., son, 4 years, of average size, well-nourished child; has several enlarged glands, rales in right apex and left base; reaction to the Von Pirquet test positive.



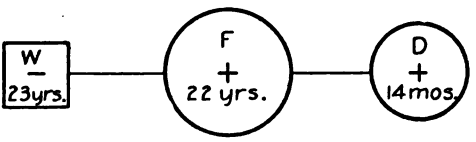
In this family of four members, three show evidence of tuberculous infection.

John C., 24th Avenue North. May 29, 1911.

This man, 22 years old, well-developed, well-nourished; shows fairly advanced pulmonary tuberculosis and has tubercle bacilli in his sputum. His condition was diagnosed in September, 1910, nine months ago, but his history indicates an active trouble as far back as the summer of 1907. He has spent four months in Hopewell Tuberculosis Hospital, leaving there much improved several months ago to go to work.

Caroline C., wife, 23 years, a small, spare, poorly nourished woman, with a long chest and slight cervical glandular enlargements; pulse 64, temperature 99; Von Pirquet test negative.

Luverne C., daughter, 14 months, a strong, well-developed baby, well-nourished; shows slight cervical glandular enlargements and a positive reaction to the Von Pirquet test.



In this family of three, there are two who show evidence of infection with tuberculosis.

Mr. F., Thomas Avenue North. January 10, 1911.

This man was not examined as he was an advanced case of pulmonary tuberculosis in the Thomas Hospital. He had tubercle bacilli in his sputum. He has since died.

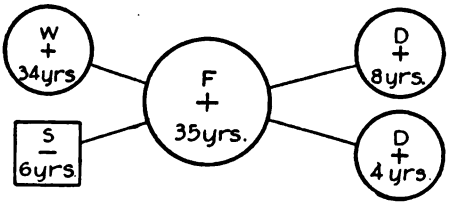
House conditions bad; four rooms poorly kept, diet fairly generous, children dirty, and kitchen badly kept. The husband used sputum cup while at home.

Carrie F., wife, 34 years, well-developed, well-nourished woman; shows no physical signs of tuberculosis, gives a positive reaction to the Von Pirquet test, but is negative to the subcutaneous test.

Ruth F., daughter, 8 years, fairly well-developed and nourished; shows cervical glandular enlargement, gives a positive reaction to the Von Pirquet test.

Clifford F., son, 6 years, fairly well-nourished, undersized, with long constricted chest, many enlarged cervical glands, prolonged expiration in right base; is negative to the Von Pirquet test.

Gladys F., daughter, 4 years, well-developed, well-nourished child; shows no physical signs of tuberculosis, but gives a positive reaction to the Von Pirquet test.



In this family of five, four individuals show evidence of tuberculous infection.

Leonard H., 24th Avenue South. March 7, 1911.

This boy, 22 years of age, was examined shortly before his death from pulmonary tuberculosis in the summer of 1910. Tubercle bacilli were present in his sputum.

Hans H., father, 58 years, very tall and slender, stooped, with a long narrow chest; was examined one year ago, but was not seen at this time. He presents a typical picture of chronic fibroid phthisis and gives a history of cough and occasional hemorrhages for several years. He is now in the State Hospital for the Insane at Rochester.

Martha H., mother, 50 years, strong, heavy woman; is negative physically, and negative to the Von Pirquet test.

Clara H. E., sister, 25 years, tall, slender, poorly nourished, with poorly formed chest; shows crackling rales in left apex, and is negative to the Von Pirquet test. She appeared undoubtedly tuberculous and was referred to the University Free Dispensary, where a few months later the disease was demonstrated by the finding of tubercle bacilli in her sputum.

Amanda H., sister, 22 years, tall and slender, poorly nourished, negative to physical examination; gives a positive reaction to the Von Pirquet test.

Herman H., brother, 19 years, tall, slender, poorly nourished, with poorly shaped chest, poor lung expansion, and evidence of an old pleuritis in right lung; gives a positive reaction to the Von Pirquet test.

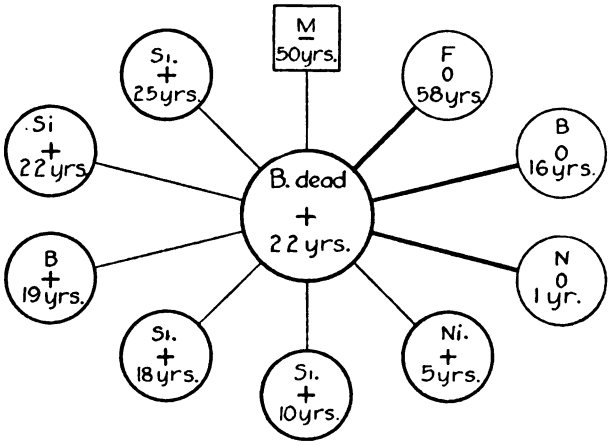
Gertrude H. B., sister, 18 years, strong, well-nourished woman, with well-formed chest; negative to physical examination, and gives a positive reaction to the Von Pirquet test.

Sidney H., brother, 16 years, was not at home. His mother says he is thin and has had a bad cough for a year. He is in the country for his health.

Julia H., sister, 10 years, is small and underdeveloped, poorly nourished, with long, narrow chest; he shows moist and crackling rales over both lungs; no bacilli could be found in her sputum at this time, but tubercle bacilli had been present in sputum; pulse 94, temperature 100.5; Von Pirquet test positive.

Evelyn E., niece, 5 years, a well-developed, well-nourished, healthy looking child; shows no physical signs of tuberculosis, but gives a positive reaction to the Von Pirquet test.

Leonard E., nephew, 1 year, said to be small, underdeveloped baby. He is in the City Hospital for treatment for tubercular hip.



Of this family of originally eleven individuals, seven were examined in this investigation; six of these show evidence of tuberculous infection. One, not examined, is being treated for tuberculosis of the hip. One, previously examined, shows evidence of tuberculous infection, one has a bad cough and is in the country for his health, and one is dead of pulmonary tuberculosis.

Ole H., 44th Avenue North. April 10, 1911.

This man, 49 years of age, has coughed for twenty years. During the last two years many tubercle bacilli have been found in his sputum. The examination shows a diffuse tuberculous process in both lungs. He has gained much under treatment during the last two years.

Inga H., wife, 38 years, good-sized, well-nourished woman, with well-shaped chest; negative to physical examination, and negative to the Von Pirquet test.

Erling H., son, 15 years, well-built boy, well-nourished, negative to physical examination, and negative to the Von Pirquet test.

Harold H., son, 14 years, large, heavy boy, very well-nourished, well-built; is negative to physical examination, and negative to the Von Pirquet test.

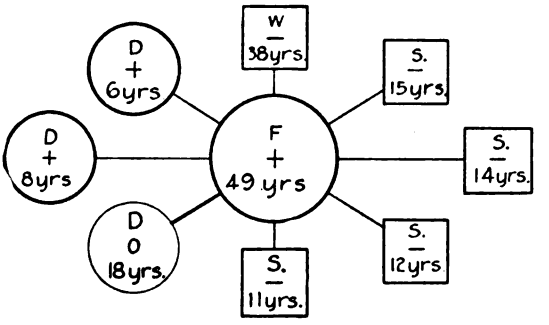
Melvin H., son, 12 years, strong, well-nourished boy; is negative to physical examination, and negative to the Von Pirquet test.

Lyle H., son, 11 years, large, strong, well-built boy, well-nourished, and negative to physical examination; negative to the Von Pirquet test.

Esther H., daughter, 8 years, tall, slender girl, with long, narrow chest; shows slight cervical glandular enlargement and negative to physical examination; gives a positive reaction to the Von Pirquet test.

June H., daughter, 6 years, well-built, heavy girl; shows slight cervical glandular enlargement; temperature 99; negative to physical examination, but shows a positive reaction to the Von Pirquet test.

Another daughter was not seen.



Of eight individuals examined in this family three show evidence of tuberculous infection.

Mrs. H., Snelling Avenue. January 26, 1911.

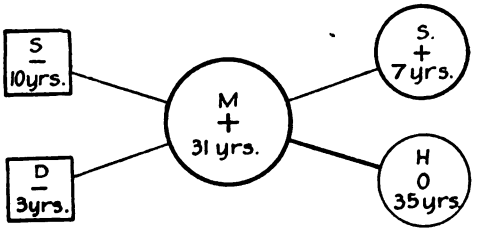
This woman, 31 years of age, fairly well-nourished, presents signs of active tuberculosis in the left lung. She has been operated on for tuberculous peritonitis. Her sputum contained tubercle bacilli two years ago, but none can be found at the present time. Her first husband died of acute pulmonary tuberculosis. She lived with her present husband and three children in a clean light house of two rooms. Guards her sputum carefully.

Percy J., son, 10 years, large, well-nourished boy; shows some cervical

glandular enlargement; negative to physical examination, and negative to the Von Pirquet test.

Alfred J., son, 7 years, is a tall, well-nourished boy with slightly constricted chest, considerable cervical glandular enlargement, enlarged tonsils and adenoids; lungs negative; gives positive reaction to the Von Pirquet test.

Helen J., daughter, 3 years, is a plump, well-nourished baby; shows cervical glandular enlargement, and has a slight dry cough; is negative to physical examination, and negative to Von Pirquet test.



In this family of five, of whom four were examined, there are two who show evidence of tuberculous infection.

Mrs. J., 6th Street South. December 1, 1911.

The mother of this family died, a few days prior to my visit, of pulmonary tuberculosis.

The father could not be seen.

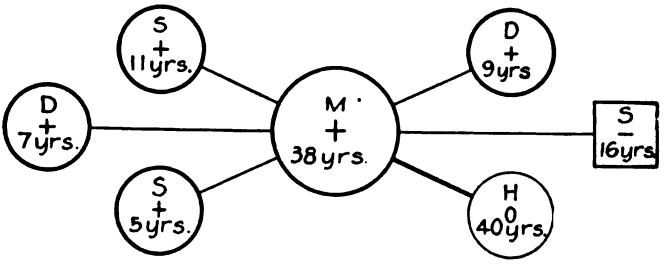
Harry J., son, 16 years, very large and strong, well-built, well-nourished young man; negative to physical examination; temperature 100; is negative to the Von Pirquet test.

Edwin J., son, 11 years, large, well-built, well-nourished boy; shows cervical glandular enlargement, negative chest, positive reaction to the Von Pirquet test.

Alice J., daughter, 9 years, tall, slender girl, fairly well-nourished, with long, narrow chest; negative to physical examination; temperature 100.4, with a positive reaction to the Von Pirquet test.

Edith J., daughter, 7 years, slight, underdeveloped, poorly nourished girl, with long, constricted chest, many rales in base of both lungs; pulse 108, temperature 100.2, respiration 26; positive reaction to the Von Pirquet test.

George J., son, 5 years, strong, well-nourished, well-built boy; with some glandular enlargement; negative to examination; shows a positive reaction to the Von Pirquet test.



In this family are six individuals, of whom five were examined. Three of these five show evidence of tuberculous infection.

Mr. J., 18th Avenue North. December 27, 1910.

Wife, age 47, large, strong, well-nourished, with well-shaped chest; shows crepitant rales in apex of left lung; Von Pirquet test negative. She lives with her children in four basement rooms where her husband lay sick for some months with pulmonary tuberculosis before dying in the City Hospital. The six people all sleep in one room twelve feet square.

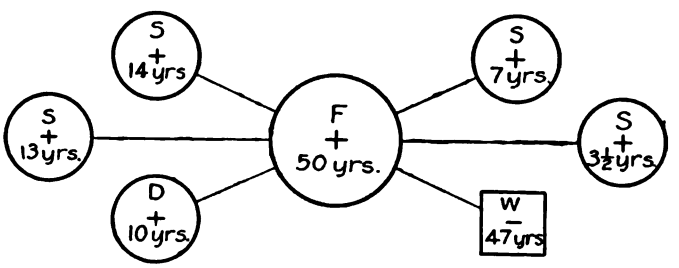
John J., son, 14 years, fairly well-nourished and developed; shows slight cervical glandular enlargement, rales and high pitched resonance in right base posteriorly; positive reaction to the Von Pirquet test.

Joseph J., son, 13 years, well-developed, well-nourished boy; negative to physical examination; pulse 100; shows positive reaction to the Von Pirquet test.

Bessie J., daughter, 10 years, well-developed, well-nourished girl; shows cervical glandular enlargement; gives positive reaction to the Von Pirquet test.

Melvin J., son, 7 years, fairly well-developed and nourished, with poorly formed chest, and cervical glandular enlargement; negative to physical examination; temperature 99.8; gives a positive reaction to the Von Pirquet test.

Iner J., son, 3½ years, a well-developed, well-nourished boy, with a poorly formed chest and enlarged cervical glands; negative to physical examination; shows a positive reaction to the Von Pirquet test.



Each member of this family of six shows evidence of tuberculous infection, except the mother.

C. M. J., Washington Avenue North. May 26, 1911.

This man died about three weeks prior to my visit in the tuberculosis ward of the Minneapolis City Hospital, where he had been for three weeks. For six months before that he had lived at home sick with pulmonary tuberculosis in a house of five, fairly large, well-ventilated, but dark rooms, with his wife and six children.

Mary J., wife, 36 years, small, poorly developed woman, with deformed spine and chest; her lungs show signs of healed tuberculous lesions; temperature 99.8; Von Pirquet test negative.

Alice J., daughter, 17 years, robust, well-nourished girl, well-developed, negative to physical examination, with poor expansion, pulse 100, temperature 99.5; shows positive reaction to the Von Pirquet test.

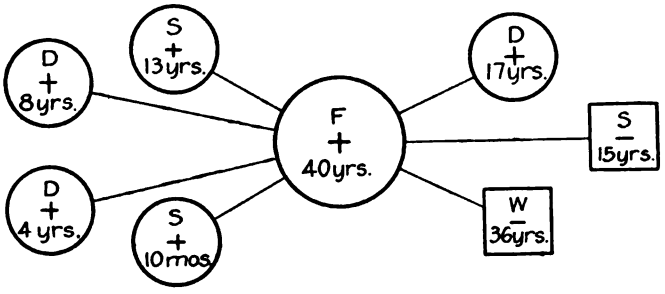
John J., son, 15 years, large, well-developed boy, fairly well-nourished, with slight cervical glandular enlargement, negative to examination, and gives negative reaction to the Von Pirquet test.

Charles J., son, 13 years, small but well-formed and well-nourished, negative to examination; temperature 99.5; shows positive reaction to the Von Pirquet test.

Elizabeth J., daughter, 8 years, small, poorly developed, poorly nourished child, with long narrow chest, slight cervical glandular enlargement, temperature 99.2; gives a positive reaction to the Von Pirquet test.

Evelyn J., daughter, 4 years, well-developed, well-nourished child, with slight cervical glandular enlargement, fine rales over right upper lobe anteriorly, pulse 94, temperature 100.2; shows a positive reaction to the Von Pirquet test.

Harry J., son, 10 months old, large fat baby, well-formed, negative to examination; shows positive reaction to the Von Pirquet test.



In this family of seven individuals, there are five showing evidence of tuberculous infection.

Fred K., Aldrich Avenue North. March 30, 1912.

This boy, 23 years old, underweight, poorly nourished, shows signs of moderately advanced pulmonary tuberculosis, with tubercle bacilli in his sputum.

The parents were not examined.

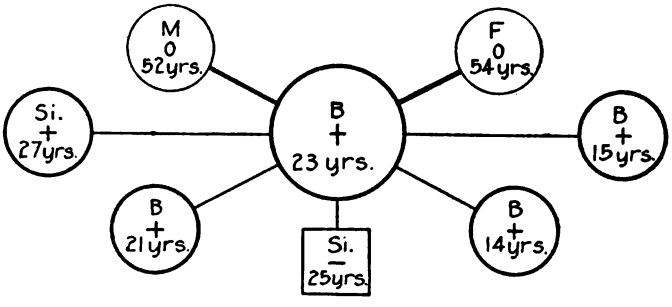
Eleanor K., sister, 27 years, slightly built, fairly well-nourished, with poorly formed chest and poor expansion; negative to examination; temperature 99; gives a positive reaction to the Von Pirquet test. This girl is said to have had pulmonary tuberculosis when a child.

Bertha K., sister, 25 years, fairly well-nourished, with poorly formed chest and fine rales in left apex posteriorly; temperature 99.2; negative to the Von Pirquet test.

Carl K., brother, 21 years, well-developed, strong, well-nourished young man, with very well-formed chest; negative to physical examination; gives a positive reaction to the Von Pirquet test.

Albert K., brother, 15 years, a well-developed, well-nourished boy; has slight cervical glandular enlargement; negative to examination; shows positive reaction to the Von Pirquet test.

Arthur K., brother, 14 years, undersized, well-nourished, well-built; shows cervical glandular enlargement; negative to examination; temperature 99; gives a positive reaction to the Von Pirquet test.



Of the six children, five show evidence of tuberculous infection.

Ben K., 23d Avenue South. April 13, 1911.

This boy, age 16, is an advanced case of pulmonary tuberculosis with many tubercle bacilli in his sputum. Has died of tuberculosis since he was seen.

Peter K., father, 52 years, heavy built man, with well-formed chest; negative to examination; temperature 99.2; gives a positive reaction to the Von Pirquet test.

Carrie K., mother, 47 years, good-sized, well-nourished woman, with long chest, slight axillary glandular enlargement, chronic skin eruption on

right forearm which she has had for eleven years; shows signs of old pleurisy on the right side; had pneumonia on the same side 24 years ago; temperature 99.4; and gives a positive reaction to the Von Pirquet test.

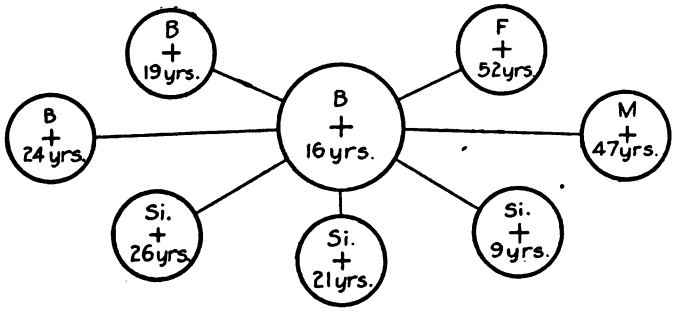
Anna K. B., sister, 26 years, advanced case of pulmonary tuberculosis with tubercle bacilli in the sputum.

Louis K., brother, 24 years, advanced case of pulmonary tuberculosis with tubercle bacilli in the sputum. Has since died.

Julia K., sister, 21 years, small, fairly well-nourished girl, with well-formed chest, slight cervical enlargement, distant breathing and egophony over left scapula; temperature 100; gives a positive reaction to the Von Pirquet test.

James K., brother, 19 years, of medium size, fairly well-nourished, with round long chest, slight cervical enlargement; negative to physical examination; temperature 99; gives a positive reaction to the Von Pirquet test.

Byrdie K., sister, 9 years, fairly well-developed, well-nourished child; is now suffering from chorea; has a long but fairly well-shaped chest, considerable cervical glandular enlargement; is negative to examination; pulse 94, temperature 99.8; has recently had tonsilitis; gives a positive reaction to the Von Pirquet test.



In this family of eight, every individual shows evidence of tuberculous infection.

Mrs. K., Seymour Avenue Southeast. June 29, 1911.

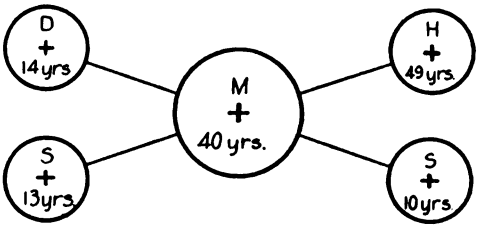
This woman, 40 years of age, is an advanced case of pulmonary tuberculosis with many tubercle bacilli in her sputum.

Charles K., husband, 49 years, a tall, spare man, fairly well-nourished, negative to examination; shows a positive reaction to the Von Pirquet test; gives a history of pleurisy ten years ago.

Marian K., daughter, 14 years, large, well-developed, well-nourished girl, negative to examination; pulse 86, temperature 99.4; shows positive reaction to the Von Pirquet test.

Harold K., son, 13 years, well-developed, well-nourished boy, with well-shaped chest; negative to examination; temperature 99.2; shows a positive reaction to the Von Pirquet test.

Horace K., son, 10 years, underdeveloped, fairly well-nourished, with poorly shaped chest and poor expansion; negative to examination; pulse 100, temperature 101; gives positive reaction to Von Pirquet test.



In this family of five, every individual shows evidence of tuberculous infection.

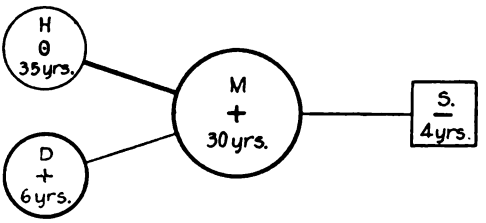
Mrs. L.

This woman has an active tuberculous lesion in the left apex and tubercle bacilli in her sputum. She nursed her brother, who died of tuberculosis six years ago.

Her husband was not seen.

M. L., daughter, 6 years, a well-developed, well-nourished child, negative physically; gives a positive reaction to the Von Pirquet test.

P. L., son, 4 years, a well-developed, well-nourished boy; shows slight cervical glandular enlargement; negative physically and negative to the Von Pirquet test.



This woman and her husband are exceptionally intelligent people and are highly educated. They have an ideal home. They have been fully aware of the danger of infection from tuberculosis and fully aware of the woman's condition. The husband was not examined. Of these three individuals, two show evidence of tuberculous infection.

Ella L., 5th Street Northeast. September 3, 1911.

This woman died of pulmonary tuberculosis four months prior to my visit in the house where the family now lives. Minneapolis Health Department records show the presence of tubercle bacilli in her sputum.

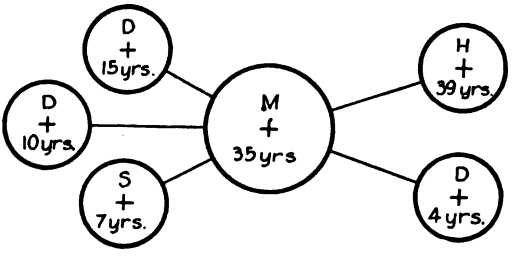
Andrew L., husband, 39 years, strong, well-nourished man; has a poorly shaped chest and signs of healed tuberculous lesion in left apex; temperature 99.1; shows a positive reaction to the Von Pirquet test.

Anna L., daughter, 15 years, well-developed, well-nourished girl, with slight cervical glandular enlargement, negative to physical examination, anemic; temperature 99.5; gives a positive reaction to the Von Pirquet test.

Mary L., daughter, 10 years, well-developed, well-nourished girl, with poorly shaped chest, slight cervical glandular enlargement and cogwheel respiration in right upper lobe; pulse 84, temperature 99.6; shows a positive reaction to the Von Pirquet test.

John L., son, 7 years, well-developed, fairly well-nourished, with poorly shaped chest and slight cervical glandular enlargement; pulse 92, temperature 99.2; negative physically, but shows a positive reaction to the Von Pirquet test.

Elizabeth L., daughter, 4 years, well-developed, well-nourished child, with slight cervical glandular enlargement; pulse 116, temperature 99; shows a positive reaction to the Von Pirquet test.



In this family of five, every individual showed evidence of tuberculous infection.

Sylvester M., 12th Avenue North. December 10, 1910.

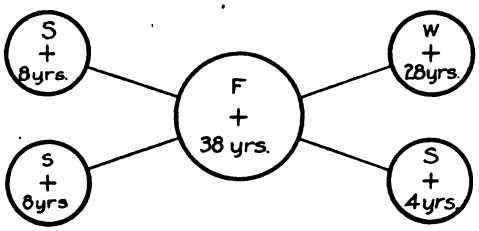
This man, 38 years, is in a very advanced stage of pulmonary tuberculosis, with many tubercle bacilli in his sputum. He has been cared for away from home much of the time during the last seven months. The rest of the time he has been at home with his wife and three children. The house conditions are poor. He has been careless about his sputum, though he well understands the risk to his family. He has since died.

Christina M., wife, 28 years, strong looking, spare woman, with a well-shaped chest and some fine rales in the right apex; Von Pirquet test negative. Tested again four months later, Von Pirquet test positive.

LeRoy M., son, 8 years, small, underdeveloped, poorly nourished boy, with poorly shaped chest and some cervical glandular enlargement; negative to physical examination; temperature 99.6; negative to the Von Pirquet test. Four months later positive to the Von Pirquet test.

George M., son, 8 years, small, poorly nourished; shows cervical glandular enlargement; negative to physical examination; temperature 100.4; Moro test positive, Von Pirquet test negative. Four months later Von Pirquet test positive.

Elmer M., son, 4 years, well-developed, well-nourished boy, showing some cervical glandular enlargement; negative physically; temperature 99.8, Moro reaction positive. Four months later Von Pirquet test positive.



In this family of five, every individual showed evidence of tuberculous infection.

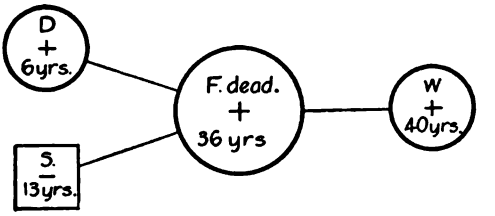
Hulda O., Cedar Avenue. May 11, 1911.

This woman, age 40, is tall and slight, has a long narrow chest, and shows signs of infiltration in middle lobe of right lung. Her husband died four years ago after an illness of two years of pulmonary tuberculosis with many tubercle bacilli in his sputum.

She lives in a small dark flat and does family sewing and rents one room to lodgers. This has been classed as an active case on account of the exposure of the whole family during the father's sickness, he being taken as the center case.

Melvin O., son, 13 years, large, strong, well-nourished boy, with poorly shaped chest; has an acute bronchitis; temperature 99; Von Pirquet test negative.

Helen O., daughter, 6 years, slender, active, fairly well-nourished girl, with well-shaped chest and slight cervical glandular enlargement; negative to physical examination; temperature 98.8; gives a positive reaction to the Von Pirquet test.



Of the three surviving members of this family, two show evidence of tuberculous infection.

Mrs. O., Pleasant Street Southeast. June 20, 1911.

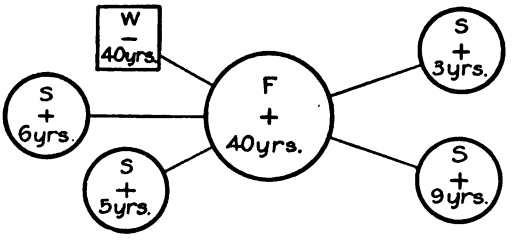
This woman's husband died of pulmonary tuberculosis about two years ago after an illness of several years. He had many tubercle bacilli in his sputum. The woman was not examined as she is a private case. She gives a negative Von Pirquet test.

Gustav O., son, 9 years, undersized, fairly well-nourished, with poorly shaped chest and general glandular enlargement; negative to physical examination; temperature 99; gives a positive reaction to the Von Pirquet test.

Carl O., son, 6 years, well-developed, well-nourished boy, shows some cervical glandular enlargement; negative physically; temperature 99.2; gives a positive reaction to the Von Pirquet test.

Ebbe O., son, 5 years, large, well-developed, well-nourished boy, showing slight cervical glandular enlargement; negative to physical examination; gives a positive reaction to the Von Pirquet test.

Swen O., son, 3 years, stout, well-nourished boy, showing some cervical glandular enlargement; negative to physical examination; temperature 99.2; gives a positive reaction to the Von Pirquet test.



In this family of five individuals, four show evidence of infection with tuberculosis.

Frank N., Main Street Northeast. July 16, 1911.

This man is well-built, fairly well-nourished, with a well-shaped chest. Both lungs show signs of active tuberculosis and the sputum contains tu-

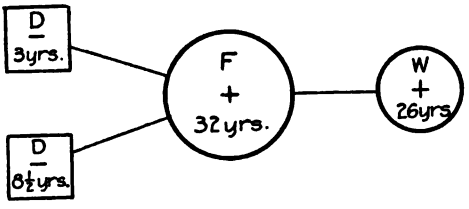
bercle bacilli. He gives a history of pleurisy twelve years ago with slow recovery. Six months ago he took a severe cold and one month later had a pulmonary hemorrhage. He went to the City Hospital at that time and stayed there until six weeks ago. He then went to work and has worked since.

The wife says that her husband is careless with his sputum. He has been away from home nearly all of his infective period.

Julia N., wife, 26 years, a large, strong, well-nourished woman, negative to examination; gives a positive reaction to the Von Pirquet test.

Anna N., daughter, 8½ years, a large, well-nourished child, showing slight cervical glandular enlargement; temperature 99.4; negative to the Von Pirquet test.

Alice N., daughter, 3 years, a stout, heavy child, showing slight cervical glandular enlargement, negative to examination, and negative to the Von Pirquet test.



In this family of four individuals, two show evidence of tuberculous infection.

Mrs. N., 24th Avenue South. September 1, 1911.

Mary N., mother, 30 years, tall, thin woman, with a long stooped chest, shows signs of healed tuberculous lesions in right upper and middle lobes. Gives a positive reaction to the Von Pirquet test.

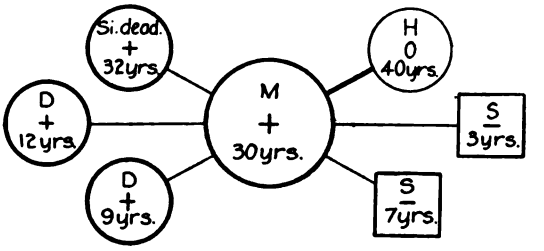
Alma N., daughter, 12 years, large, well-nourished girl with a well-formed chest; shows slight cervical glandular enlargement; negative to physical examination; gives a positive reaction to the Von Pirquet test.

Dora N., daughter, 9 years, well-developed, well-nourished girl; shows slight cervical glandular enlargement; negative to physical examination; shows a positive reaction to the Von Pirquet test.

John N., son, 7 years, large, well-nourished boy, with slight cervical glandular enlargement. He is very deficient mentally as a result of an acute meningitis and it was impossible to examine him. The Moro test was negative.

James N., son, 3 years, sturdy, well-nourished boy, with slight cervical glandular enlargement; negative physically; negative to the Von Pirquet test.

A sister of the mother of this family recently died of tuberculous peritonitis in this house. The mother, who shows signs of a healed pulmonary tuberculosis, gives a history of cough, loss of weight, and pulmonary hemorrhages prior to seven years ago at which time her health improved. The children over seven years of age show evidence of tuberculous infection and those under that age do not.



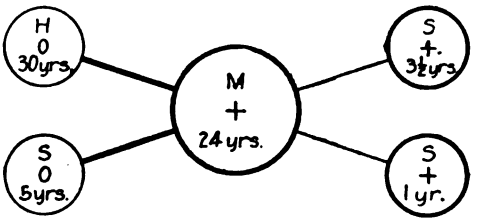
In this group of five individuals, three show evidence of tuberculous infection.

Mrs. Ida R., Oakland Avenue. March 1, 1911.

This woman, age 24, slight, fairly well-nourished, with well-shaped chest, is an advanced open case of pulmonary tuberculosis. There are many tubercle bacilli in her sputum. She has been with these two children and has had all the care of them much of the time since she became sick. An older child has been away from home most of the time and was not examined. The husband could not be examined. The house conditions are bad, diet poor and poorly prepared. Sputum is guarded.

Roy R., son, 3½ years, well-developed, well-nourished child; has a well-formed chest; negative to physical examination; pulse 108, temperature 99.8; shows a positive reaction to the Von Pirquet test.

Warren R., son, 1 year, small, fairly well-nourished; negative to physical examination; pulse 120, temperature 100; gives a positive reaction to the Von Pirquet test.



In this family of five only three could be examined, all of whom showed evidence of tuberculous infection.

Joseph R., Snelling Avenue. December 29, 1911.

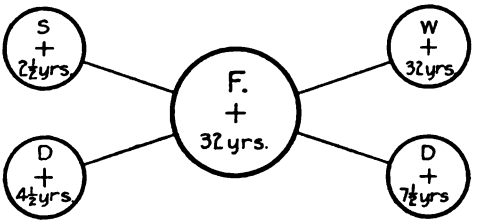
This man, 32 years, tall, well-developed, well-nourished, is an active open case of pulmonary tuberculosis with many tubercle bacilli in his sputum.

Mary R., his wife, 32 years, is a large, strong appearing woman with a flat chest; has poor expansion; is negative to examination; pulse 94, temperature 100; gives a positive reaction to the Von Pirquet test.

Mary R., daughter, 7½ years, small, well-nourished girl with a well-formed chest; shows slight cervical glandular enlargement; negative to physical examination; temperature 99; gives a positive reaction to the Von Pirquet test.

Flossie R., daughter, 4½ years, small, fairly well-nourished; shows many enlarged cervical glands; negative to physical examination; gives a positive reaction to the Von Pirquet test.

Jerry R., son, 2½ years, heavy, well-nourished baby, with a broad, flat chest, many enlarged cervical glands; negative to physical examination; gives a positive reaction to the Von Pirquet test.



In this family of five, each individual shows evidence of tuberculous infection.

Mrs. P. S., 24th Avenue North. January 24, 1911.

This woman, age 27, who is a moderately advanced case of pulmonary tuberculosis with tubercle bacilli in her sputum, gives a rather remarkable history of exposure. She could at first give no history of exposure as there had never to her knowledge been a case of tuberculosis in her family or among her intimate associates. On further inquiry the following facts were developed. In the spring of 1909 she entertained a guest for a period of three weeks. This man was sick and coughed badly, raised much sputum, discharging the sputum in his handkerchief and drying the handkerchief, when saturated, over or under the kitchen stove. After three weeks they discovered that he was tuberculous and asked him to leave. Six or eight months later in the winter of 1909 and 1910 the family moved into a new house which had never been occupied. Three months later, in the spring of 1910, Mrs. S. developed pleurisy. During the summer of 1910 Mr. S. developed pleurisy. In the fall of 1910 one of the children began to fail and

developed fever. At the present time, namely three months later, the following conditions are present:

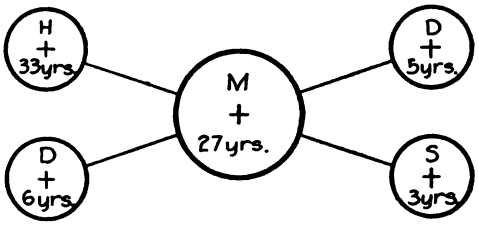
Mrs. S., 27 years, well-developed, poorly nourished woman; a moderately advanced open case of pulmonary tuberculosis with many bacilli in her sputum.

Peter S., her husband, 33 years, large, strong, well-nourished man, with poorly shaped chest; has slight curvature of the spine, shows rather vague signs on physical examination; pulse 90; gives a positive reaction to the Von Pirquet test, and a positive reaction to the subcutaneous test.

Beatrice S., daughter, 6 years, well-developed, well-nourished child; shows some cervical glandular enlargement; negative to physical examination and shows a positive reaction to the Von Pirquet test.

Pearl S., daughter, 5 years, a large, very well-developed, well-nourished child, shows enlarged cervical glands; negative to physical examination and gives a positive reaction to the Von Pirquet test.

Earling S., son, 3 years, good-sized, well-nourished child with a well-shaped chest; shows some cervical enlargement; negative to physical examination; temperature 100, with a positive reaction to the Von Pirquet test.



Each member of this family of five persons shows evidence of tuberculous infection.

George S., 19th Avenue Northeast. July 9, 1912.

The mother of this family died of pulmonary and laryngeal tuberculosis a few days prior to my visit. She had many tubercle bacilli in her sputum. This large family of eight children have been poorly clothed and poorly fed and poorly cared for in every way. They are a hardy lot as a whole and practically live out of doors.

George S., father, 45 years, large, well-built man, negative to physical examination, and negative to the Von Pirquet test.

Joseph S., son, 13 years, tall, poorly nourished, with a long narrow chest, some cervical glandular enlargement, crepitant rales and dullness in right lung; temperature 99.2; gives positive reaction to the Von Pirquet test.

Helen S., daughter, 11 years, tall, fairly well-nourished girl, with a

broad chest, slight cervical glandular enlargement, rales and dullness in both lungs; pulse 98, temperature 99; gives a positive reaction to the Von Pirquet test.

Margaret S., daughter, 9 years, well-developed, well-nourished girl; shows some cervical glandular enlargement and some cogwheel respiration in left lung; pulse 104, temperature 99.4; gives a positive reaction to the Von Pirquet test.

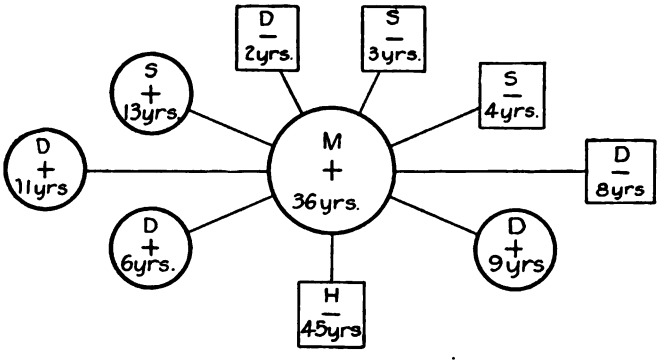
Anna S., daughter, 8 years, well-built, well-nourished child; shows many enlarged cervical glands; negative to physical examination; pulse 100, temperature 99.8; negative to Von Pirquet test.

Elsie S., daughter, 6 years, small, poorly developed, poorly nourished child, with many enlarged glands; negative to physical examination; gives positive reaction to the Von Pirquet test.

Lawrence S., son, 4 years, well-developed, well-nourished boy, showing many enlarged cervical glands, poorly shaped chest; physical examination negative; pulse 104; gives negative reaction to the Von Pirquet test. This boy is an imbecile.

George S., Jr., son, 3 years, well-formed, well-nourished boy, negative to physical examination; pulse 108, temperature 99; Von Pirquet test negative.

Theresa S., daughter, 2 years, heavy, well-developed baby, negative on physical examination, negative to the Von Pirquet test.



In this family of nine individuals, four show evidence of tuberculous infection.

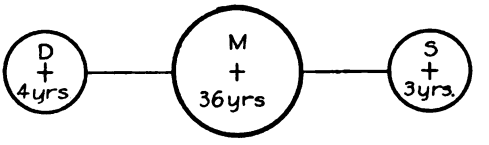
Carrie S., 16th Avenue South. November 20, 1911.

This woman, 36 years, is in an advanced stage of pulmonary tuberculosis with many tubercle bacilli in her sputum.

Florence S., daughter, 4 years, heavy, well-developed child; shows enlarged cervical glands; negative to physical examination; temperature 99; positive to the Von Pirquet test.

Howard S., son, 3 years, heavy, well-developed baby; has many enlarged cervical glands, one of which is broken down, is negative to physical examination, but shows positive reaction to the Von Pirquet test.

This woman's mother died of tuberculosis twenty-three years ago; her father from the same cause six years later. She nursed them both. One sister died of tuberculosis fourteen years ago, another five years ago. One other sister is dead, but the cause of death is not known. She has three brothers, one of whom, she says, has weak lungs.



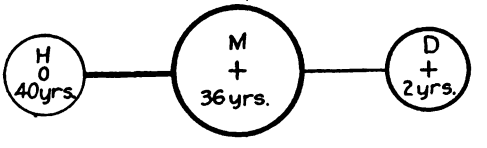
This family of three individuals shows evidence of tuberculous infection in all the members.

Sophie S., 29th Avenue South. February 9, 1911.

This woman, 36 years, well-built, well-nourished, has moderately advanced pulmonary tuberculosis with tubercle bacilli in her sputum. She with her husband and baby live in a one-room house with a seven-foot ceiling. Her husband's mother and sister died of tuberculosis and another sister is in Hopewell Tuberculosis Hospital. She was closely associated with all these people.

Mr. S., husband, could not be examined.

Pearl S., daughter, 2 years, very fat heavy baby, has tuberculous lesions on her right thumb and on two toes on her left foot. Her lungs are negative to examination; she gives a positive reaction to the Von Pirquet test.



In this family the two who were examined show evidence of tuberculous infection.

Theodore Z., Colfax Avenue North. January 27, 1912.

This man, 44 years, is a moderately advanced open case of pulmonary tuberculosis. His sputum has contained tubercle bacilli for many months. The father of this family is known to have had tubercle bacilli in his sputum for at least one year. He is a well-trained patient and has carefully isolated himself from his family.

Amelia Z., wife, 40 years, is a small, well-nourished woman, with well-developed chest; shows a small area of consolidation in right lung; temperature 99.2, Von Pirquet test negative; the subcutaneous tuberculin test, used on account of lung signs, was also negative. Three months later the visiting nurse reports that she had a pulmonary hemorrhage.

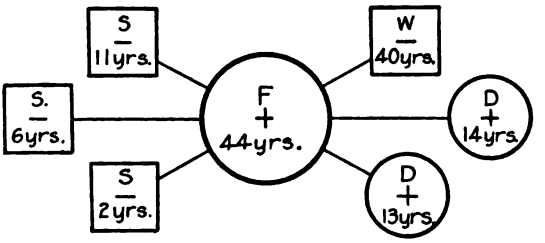
Mathilda Z., daughter, 14 years, underdeveloped, poorly nourished girl, with a long narrow chest, cervical glandular enlargement, poor expansion, rales and dullness in right upper lobe. Sputum is negative, pulse 116, temperature 98, Von Pirquet test positive, subcutaneous test positive.

Amelia Z., daughter, 13 years, well-developed, very well-nourished girl, with well-shaped chest; is negative to physical examination, gives a positive reaction to the Von Pirquet test, and a positive reaction to the subcutaneous test. Five milligrams of old tuberculin were used in the subcutaneous test.

Theodore Z., son, 11 years, small, poorly nourished boy with a long narrow chest, much cervical glandular enlargement; negative to physical examination; negative to the Von Pirquet test.

Fred Z., son, 6 years, small, poorly nourished boy, with a long stooped chest; negative to physical examination; temperature 99.3; gives a negative reaction to the Von Pirquet test.

Al. Z., son, 2 years, well-developed, well-nourished baby; negative to physical examination and negative to the Von Pirquet test.



In this family of seven individuals, three show evidence of tuberculous infection.

The center cases of the four following groups are classed as latent as they show clinical signs of pulmonary tuberculosis and are reported as having had tubercle bacilli in the sputum, though none could be found at the time of my investigation.

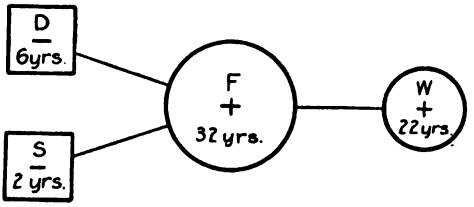
John C., 44th Avenue South. June 13, 1911.

This man, 32 years old, is large and powerfully built; there are a few rales and slight dullness in the upper lobe of the left lung; no tubercle bacilli have ever been found in his sputum; gives a positive reaction to the Von Pirquet test.

Henrietta C., wife, 22 years, is a strong, well-nourished woman who presents no physical signs of tuberculosis except a positive reaction to the Von Pirquet test. She was very definitely exposed to tuberculosis eleven years ago when two sisters died of the disease.

Henrietta C., daughter, 6 years, is a well-nourished, well-developed child with slight cervical glandular enlargement; negative to physical examination and negative to the Von Pirquet test.

John C., Jr., son, 2 years, large, well-nourished child, shows a slight cervical glandular enlargement; negative to physical examination and negative to the Von Pirquet test.



In this family of four individuals, two show evidence of tuberculous infection. Both parents are infected, possibly from different sources. Neither of the children shows signs of infection. Neither parent has shown tubercle bacilli in the sputum.

Carl C., 12th Street South. September 26, 1911.

This man, 30 years of age, strong appearing and well-nourished, with barrel-shaped chest, was diagnosed tuberculous three years ago and tubercle bacilli were found in his sputum at that time. At present he appears to be an arrested or healed case. Shows limited lung expansion, and a positive reaction to the Von Pirquet test. On account of the unfortunate circumstance of this man's losing his position through the fact becoming known that he was suspected of being tuberculous he presented himself to one of our specialists for further examination. The subcutaneous tuberculin test was applied and he gave a positive reaction, showing that somewhere he still has a focus of tuberculous infection.

Mary C., wife, 29 years, small, poorly nourished woman, presents no signs of tuberculosis and is negative to the Von Pirquet test.

Carl C., son, 8 years, small underdeveloped child, fairly well-nourished, with a well-shaped chest, shows slight cervical glandular enlargement; temperature 99.5; negative to the Von Pirquet test.

Joseph C., son, 6 years, fairly well-developed, well-nourished boy, with chest constricted at the base on the left side, slight cervical glandular enlargement, and definite signs of tuberculous infection in the left lung; pulse 86, temperature 99.5; and positive reaction to the Von Pirquet test. Was

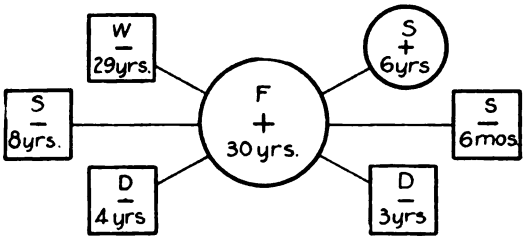
diagnosed tuberculous one year ago, has spent this summer in the visiting nurses' tuberculosis camp and is much improved.

Mary C., daughter, 4 years, of average size, well-nourished and well-developed, is negative to physical examination and negative to the Von Pirquet test.

Aggie C., daughter, 3 years, large, well-nourished, well-developed child, with slight cervical glandular enlargement; is negative to physical examination and negative to the Von Pirquet test.

Anthony C., son, 6 months, is suffering from extreme malnutrition but was negative to the Moro test which was the only one that could be used in this case.

These children have but scant care, although their home conditions are not very bad.



In this family of seven individuals, only two show evidence of tuberculous infection.

Anna O., Knox Avenue North. January 17, 1911.

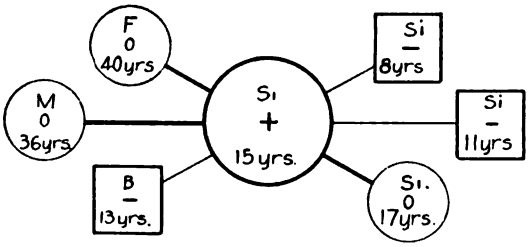
Anna O., 15 years, good-sized, well-nourished girl; shows very slight signs in the left lung. No tubercle bacilli were found in her sputum. The Von Pirquet test was not made, but she reacted positively to the subcutaneous test.

Arnold O., brother, 13 years, large, very well-nourished boy, shows slight cervical glandular enlargement; negative to examination, negative to the Von Pirquet test.

Hilda O., sister, 11 years, well-developed, well-nourished girl; negative to examination, negative to the Von Pirquet test.

Ruth O., sister, 8 years, well-developed and well-nourished girl, with some cervical glandular enlargement; negative to examination and negative to the Von Pirquet test.

The father, mother, and one sister were not examined.



In this family of seven individuals, four were examined and only the center case showed evidence of tuberculous infection.

Patrick C., Lyndale Avenue North. February 4, 1911.

This man, 38 years, was reported as having been sick with pulmonary tuberculosis for the last three years, but not ill enough to be disabled for any length of time. He appears strong and well-nourished, has a well-shaped chest, shows no abnormal signs on examination of chest, complains of pain in his side; his sputum has been reported as showing tubercle bacilli recently, though none were found at this time. His pulse was 65, temperature 98, and the Von Pirquet test showed a positive reaction.

Margaret C., his wife, 36 years, large, robust appearing woman, with a flat chest and poor expansion. There is distant breathing in the middle lobe of the right lung. Temperature 99.4, Von Pirquet test positive. She says that two years ago she was very sick, was greatly reduced in weight and showed many tubercle bacilli in the sputum. She has been in the tuberculosis camp for two summers and is now in very good condition.

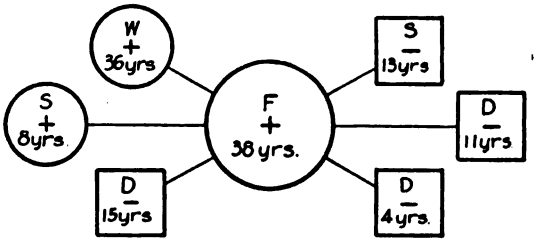
Jennie C., daughter, 15 years, large, well-developed girl; left chest rather retracted at the apex; pulse 90, temperature 99, Von Pirquet test negative.

Nicholas C., son, 13 years, large, strong appearing boy, with slight cervical glandular enlargement; negative to physical examination and negative to the Von Pirquet test.

Laura C., daughter, 11 years, an exceptionally well-developed and healthy looking girl. Nothing abnormal in her physical condition could be found, and she is negative to the Von Pirquet test.

John C., son, 8 years, small, poorly developed, and poorly nourished boy with some cervical glandular enlargement; Von Pirquet test positive.

Mary C., daughter, 4 years, well-developed girl, with few enlarged cervical glands; negative to examination; Von Pirquet test negative.



In this family of five children with both father and mother reported as having had tubercle bacilli in their sputum, only one child shows evidence of tuberculous infection.

The following two cases are classed as healed cases as they presented signs of old tuberculous pulmonary lesions and did not react to the subcutaneous test.

Caroline E., Cedar Avenue. November 5, 1911.

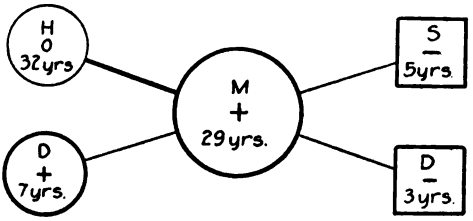
This woman, 29 years, well-nourished, well-developed, was definitely exposed to tuberculosis for a period of four years up to thirteen years ago, her father dying of the disease. Five years ago she was diagnosed tuberculous. She presents signs of an old tuberculous lesion in a small area in the right lung. Temperature 99, positive reaction to Von Pirquet test, and negative to the subcutaneous test.

The father was not examined.

Esther E., daughter, 7 years, poorly nourished, with slight cervical glandular enlargement; pulse 90, temperature 99, negative to physical examination, and gives a positive reaction to the Von Pirquet test.

Roy E., son, 5 years, well-developed, well-nourished boy, is negative to examination and negative to the Von Pirquet test.

Mabel E., daughter, 3 years, very well-nourished, well-built child, shows slight cervical glandular enlargement; pulse 96, temperature 99.3, Von Pirquet test negative.



In this family of five only two show evidence of tuberculous infection. From the mother's history it would seem that she had tubercle bacilli in her sputum five years ago and at that time infected her daughter Esther, the only one now in the family showing evidence of tuberculous infection.

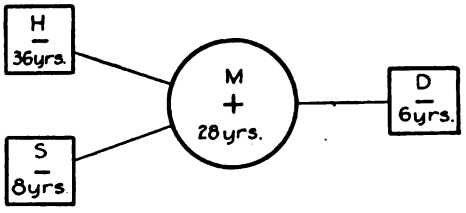
Josie N., 42d Avenue South. March 21, 1911.

This woman, 28 years old, strong and well-nourished, shows plain signs of healed pulmonary lesion, still coughs a little and gives a history of hemorrhages six months and one year ago. Can get no record of tubercle bacilli having been found in her sputum. She gave a positive reaction to the Von Pirquet test and was negative to the subcutaneous test.

Vincent N., husband, 36 years, strong, well-built, well-nourished man, negative to physical examination, negative to the Von Pirquet test.

Frank N., son, 8 years, large, well-nourished boy, negative to physical examination and negative to the Von Pirquet test.

Rose N., daughter, 6 years, large, well-nourished girl, with slight cervical glandular enlargement, negative to physical examination and negative to the Von Pirquet test.



There is no evidence of tuberculous infection in any of the four members of this family other than the center case.

NON-TUBERCULOUS GROUPS

The following ten families were found to be non-tuberculous and are so classed. They are used as controls.

Alfred F., 11th Avenue South. December 26, 1911.

Is a large, strong looking man, 32 years, is negative to physical examination, and negative to the Von Pirquet test.

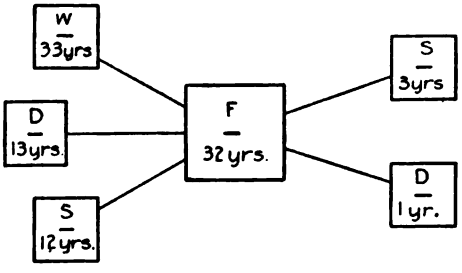
Bertha F., wife, 33 years, is a large, well-nourished woman, negative to physical examination, and negative to the Von Pirquet test.

Lillian F., daughter, 13 years, extra well-developed, well-nourished girl, negative to physical examination, and negative to the Von Pirquet test.

John F., son, 12 years, extra well-developed and well-nourished; shows slight cervical glandular enlargement; negative to physical examination, and negative to the Von Pirquet test.

Earl F., son, 3 years, strong, healthy looking child, well-developed, with slight cervical glandular enlargement, negative to physical examination, negative to the Von Pirquet test.

Dorothy F., daughter, 1 year, strong, healthy well-nourished baby, negative to physical examination, negative to the Von Pirquet test.



This family was reported by the visiting nurses for diagnosis. They had been reported to the visiting nurses as tuberculous or suspicious. Their house conditions were comfortable and fairly hygienic. Diet nourishing. There was no trace of tuberculous infection in the family.

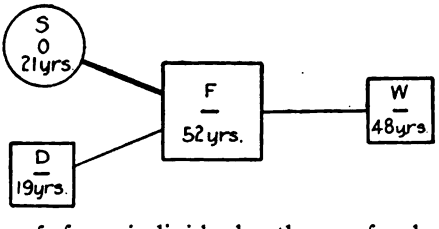
Herman B., 2d Street East. February 2, 1911.

This man, 52 years, well-built, well-nourished, with a barrel-shaped chest, has chronic cough and raises much sputum; can find no evidence of lung involvement though he has chronic bronchitis. No tubercle bacilli could be found in his sputum. Pulse 54, temperature 97; no specific test was made. He had pneumonia two years ago and has coughed ever since. He is a hard drinker and works but little. He says he has been a dispensary patient for a long time, but there is no record of tubercle bacilli having been found in his sputum there.

Emma B., wife, 48 years, large, strong, well-nourished woman, with well-formed chest; negative to physical examination; pulse 84, temperature 97.8; Von Pirquet test not made.

Marie B., daughter, 19 years, slender, anemic, fairly well-nourished, with well-formed chest, but poor expansion, complains of pain in the region of the heart; negative physical examination; pulse 72, temperature 98.6; Von Pirquet test not made.

One son was not examined. The family live in four basement rooms, dark and unventilated but clean. Diet nourishing.



In this family of four individuals, three of whom were examined, no evidence of tuberculous infection could be found.

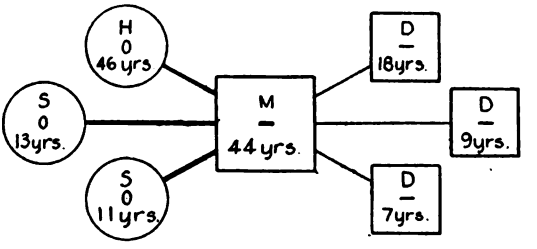
Barbara F., 14th Avenue South. August 3, 1911.

This woman, 44 years of age, small but well-nourished, is negative to examination, and negative to the Von Pirquet test.

Mamie F., daughter, 18 years, well-nourished, well-developed girl, negative to examination, and negative to the Von Pirquet test.

Delia F., daughter, 9 years, tall slender girl, with long narrow chest; is negative to physical examination and negative to the Von Pirquet test.

Julia F., daughter, 7 years, well-developed, well-nourished child, shows slight cervical glandular enlargement; negative to examination, negative to the Von Pirquet test.



In this family of seven, four were examined. None of those examined showed evidence of tuberculous infection. The father and two sons could not be examined. The mother was the reported case. She was a new Health Department case who had not been examined and was referred to me as a suspicious case.

David G., Queen Avenue North. February 24, 1912.

This man, tall, well-developed, 52 years, has short broad chest and presents a few obscure signs on physical examination. Von Pirquet test negative and subcutaneous tuberculin test negative.

Anna G., wife, 44 years, a strong, well-nourished woman, well-developed; negative to physical examination, gives a positive reaction to the Von Pirquet test and a positive reaction to the subcutaneous tuberculin test.

Rosarie G., son, 18 years, strong, well-developed, well-nourished boy; shows very slight cervical glandular enlargement; negative to physical examination and negative to the Von Pirquet test.

Pearl G., daughter, 16 years, well-developed, well-nourished girl; negative to physical examination, and negative to the Von Pirquet test.

Mary Ann G., daughter, 6 years, small, fairly well-nourished, with slight cervical glandular enlargement; negative to physical examination and negative to the Von Pirquet test.

Alexander G., son, 4 years, poorly developed, poorly nourished child,

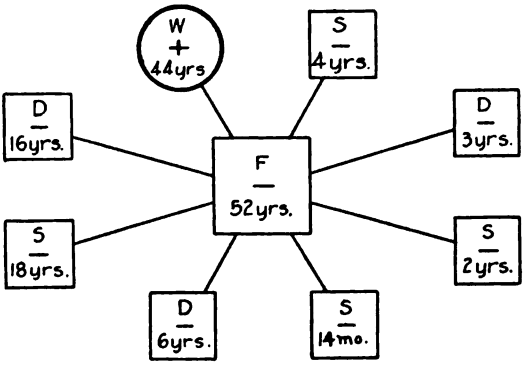
with slight cervical glandular enlargement; negative to physical examination; temperature 99; is negative to the Von Pirquet test.

Jenette G., daughter, 3 years, well-developed, well-nourished child; shows slight cervical glandular enlargement; temperature 99.4; negative to physical examination and negative to the Von Pirquet test.

Frederick G., son, 2 years, well-developed, well-nourished child; shows slight cervical glandular enlargement; negative to physical examination, negative to the Von Pirquet test.

William G., son, 14 months, well-developed, well-nourished baby, with slight cervical glandular enlargement; negative to examination and negative to the Von Pirquet test.

This family is remarkable in some respects. The father was diagnosed as tuberculous six years ago, according to his report, and has been under the observation of the visiting nurses for much of the time since then. He says he has had hemorrhages and tubercle bacilli in his sputum, but has never lost much weight and has worked some every year. No evidence of present or past tuberculous infection can be found in him. His wife, who has no history of tuberculosis as far as could be found and presents no physical signs of the disease, shows a marked reaction to the specific tests.



In this family of nine individuals only one shows evidence of tuberculous infection and that one an unsuspected individual.

Olive H., 20th Avenue North. June 6, 1911.

This woman, 36 years, strong and well-nourished, was reported to the visiting nurses as tuberculous three years ago and although she has been recently pronounced non-tuberculous, the family was examined by request. She is negative physically and negative to the Von Pirquet test.

Hazel H., daughter, 15 years, well-developed, well-nourished girl; negative to physical examination and negative to the Von Pirquet test.

Olive H., daughter, 13 years, well-developed, well-nourished girl; negative physically and negative to the Von Pirquet test.

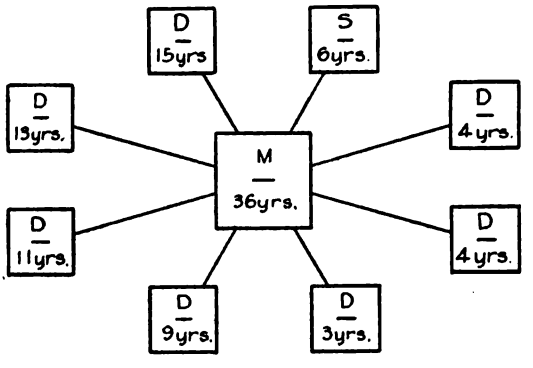
Pearl H., daughter, 11 years, well-developed, well-nourished girl; negative physically and negative to the Von Pirquet test.

Gladys H., daughter, 9 years, well-developed, fairly well-nourished girl; has several cervical enlarged glands, negative to physical examination, negative to the Von Pirquet test.

Clarence H., son, 6 years, good-sized, well-developed, well-nourished boy, negative physically, and negative to the Von Pirquet test.

Stella and Della, daughters, 4 years, well-developed, well-nourished twin girls; both negative to physical examination and negative to the Von Pirquet test.

Dorothea H., daughter, 3 years, well-developed, well-nourished child; negative to physical examination, negative to the Von Pirquet test.



This family of nine individuals which has been supervised as a tuberculous family for a long time shows no evidence of tuberculous infection in any member.

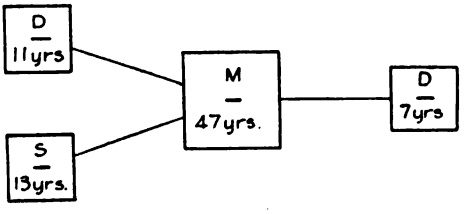
Ida M., Riverside Avenue. December 30, 1911.

This woman, 47 years old, is well-developed, poorly nourished, with a well-shaped chest; negative to physical examination, negative to the Von Pirquet test.

Theodore M., son, 13 years, well-developed, fairly well-nourished, anemic; negative on physical examination and negative to the Von Pirquet test.

Marie M., daughter, 11 years, well-developed, well-nourished girl; negative physically, negative to the Von Pirquet test.

Lillian M., daughter, 7 years, well-developed, well-nourished girl; negative physically and negative to the Von Pirquet test.



This family has been under supervision for some time. There is no evidence of tuberculous infection to be found in any member.

William M., Thomas Avenue North. March 6, 1912.

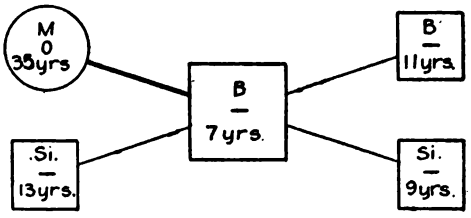
This boy with his brother and two sisters was given as a suspicious case by the Health Department. William M. is 7 years, well-developed, extra well-nourished, with well-shaped chest; negative to physical examination and negative to the Von Pirquet test.

The mother was not examined.

Sadie M., sister, 13 years, tall, well-developed, well-nourished girl, showing some cervical glandular enlargement; physical examination negative; pulse 104; Von Pirquet test negative.

George M., brother, 11 years, well-developed, fairly well-nourished boy; shows long chest, with few rales in right lung; has coughed for five or six years; Von Pirquet test negative.

Addie M., sister, 9 years, short, heavy, very well-developed girl; shows slight cervical glandular enlargement; negative on physical examination and negative to the Von Pirquet test.



In this family of four children no evidence of tuberculous infection was present.

Pearl R., 2d Street North. January 25, 1911.

This girl, 18 years, was reported to the visiting nurses as a case of pulmonary tuberculosis two years ago. She has been in the tuberculosis camp two summers and under tuberculosis precautions for two years. She coughs very little, presents no signs on physical examination, and is negative to the Von Pirquet test. Father and mother not examined.

Arthur R., brother, 16 years, small, underdeveloped boy, poorly nourished, with broad flat chest, and considerable cervical glandular enlargement; left lung expands poorly; pulse 104, temperature 98; Von Pirquet test negative.

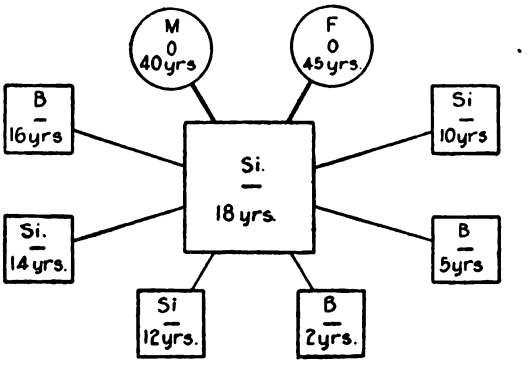
Mabel R., sister, 14 years, large, well-nourished girl; has long deep chest, constricted at the base, and slight cervical glandular enlargement; negative to physical examination, has poor expansion; pulse 85, temperature 99; Von Pirquet test negative.

Lillian R., sister, 12 years, tall, poorly nourished girl, with long narrow chest, slight cervical glandular enlargement; negative to physical examination; pulse 66, temperature 97.2; negative to the Von Pirquet test.

Maude R., sister, 10 years, well-developed, fairly well-nourished girl, with well-shaped chest; negative to physical examination; suffering from la grippe; pulse 110, temperature 100.8; Von Pirquet test negative.

Roy R., brother, 5 years, well-grown, well-nourished boy, showing some cervical glandular enlargement; temperature 99; negative on physical examination and negative to the Von Pirquet test.

Robert R., brother, 2 years, normally developed baby, with slight cervical glandular enlargement; negative on physical examination and negative to the Von Pirquet test.



The house conditions here are bad. Small, dark, dirty rooms. Pearl has a room to herself, but eight others sleep in two rooms. Can find no evidence of tuberculous infection in this family.

Mrs. Anna V., 21st Avenue South. February 27, 1911.

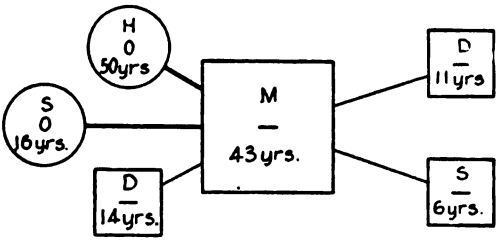
This woman, 43 years, poorly nourished, with a barrel-shaped chest, has had asthma for years. No tubercle bacilli have ever been found in her sputum. She was examined by the writer a year ago and she is now in the same condition as at that time. She shows no evidence of tuberculosis. Is negative to the Von Pirquet test.

The father and one son were not examined.

Gladys V., daughter, 14 years, very large, well-developed girl, well-nourished, negative to physical examination, negative to the Von Pirquet test.

Mary V., daughter, 11 years, very large, well-nourished girl, negative physically, and negative to the Von Pirquet test.

Edward V., son, 6 years, large, well-nourished boy, negative to physical examination, negative to the Von Pirquet test.



In this family of six individuals, four were examined and none of them showed evidence of tuberculous infection.

Benjamin W., Lyndale Place. May 21, 1911.

This man, 45 years, is well-built and well-nourished, has chronic bronchitis, and gives a history of asthma; pulse 68, temperature 98.6; Von Pirquet test negative, subcutaneous test negative two years ago.

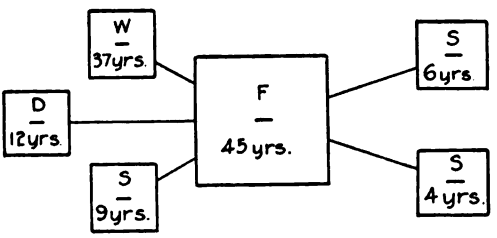
Fanny W., wife, 37 years, well-developed, fairly well-nourished, negative physically, negative to the Von Pirquet test.

Jennie W., daughter, 12 years, slight, underdeveloped girl, fairly well-nourished, with poorly shaped chest, anemic; physical examination shows a heart lesion; pulse 84, temperature 100; Von Pirquet test negative.

Allie W., son, 9 years, slight, underdeveloped, poorly nourished boy, with poorly shaped chest; has chronic bronchitis; pulse 98, temperature 99.8; Von Pirquet test negative.

Aaron W., son, 6 years, short, heavy boy, with well-formed chest; negative to physical examination, negative to Von Pirquet test.

Isadore W., son, 4 years, short, heavy child; has well-shaped chest; negative physically and negative to the Von Pirquet test.



Of this family three members, the father, age 45, Allie, age 9, and Jennie, age 12, have been reported to the visiting nurses as tuberculous. The only one presenting suspicious signs is Allie. In the absence of a positive Von Pirquet he is classed negative. The house is light, roomy but ill-ventilated. Diet insufficient. They have been supervised as tuberculous cases for two or three years.

The following five families were selected as non-tuberculous families and are used as controls, together with the preceding ten families, who proved on examination to be non-tuberculous:

Nicholas C., 19th Avenue Southeast. May 27, 1912.

The father of this family could not be examined.

Mrs. Anna C., 30 years, robust, well-developed woman, negative to physical examination, gives a positive reaction to the Von Pirquet test.

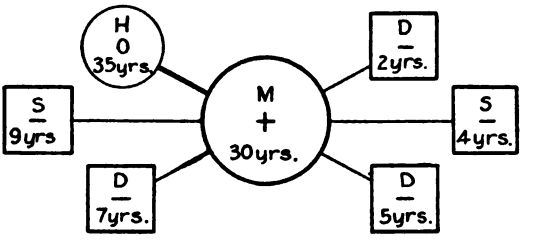
Henry C., son, 9 years, well-developed, well-nourished boy, negative to examination, negative to the Von Pirquet test.

Lucile C., daughter, 7 years, well-developed, well-nourished child, negative to physical examination, negative to the Von Pirquet test.

Esther C., daughter, 5 years, slight, underdeveloped, poorly nourished child, negative to examination, and negative to the Von Pirquet test.

Ralph C., son, 4 years, slender, poorly nourished child, negative to physical examination, negative to the Von Pirquet test.

Isabel C., daughter, 2 years, well-developed, well-nourished child, negative to physical examination, negative to the Von Pirquet test.



In this family of seven individuals who have never been exposed to tuberculosis there is evidence of tuberculous infection in one individual.

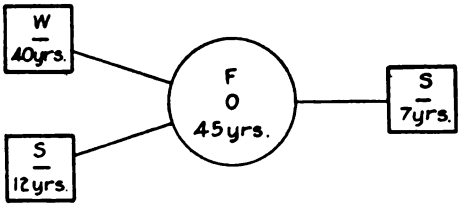
T. G. C., 19th Avenue Southeast. May 27, 1912.

This man was not examined.

P. C., wife, 40 years, who is stepmother to these boys, is a slight, poorly nourished woman, who is negative to physical examination and negative to the Von Pirquet test.

Edmund C., son, 12 years, well-developed, well-nourished boy, negative to physical examination, negative to the Von Pirquet test.

Morris C., son, 7 years, a slight, underdeveloped boy, negative to physical examination, and negative to the Von Pirquet test.



In this family of four individuals, three were examined and none showed evidence of tuberculous infection.

David D., 21st Avenue Southeast. May 27, 1912.

This man, father of this family, was not examined.

Lilian D., wife, 34 years, strong, well-nourished woman, negative to physical examination and negative to Von Pirquet test.

Ethel D., daughter, 14 years, well-developed, well-nourished girl, negative to physical examination and negative to the Von Pirquet test.

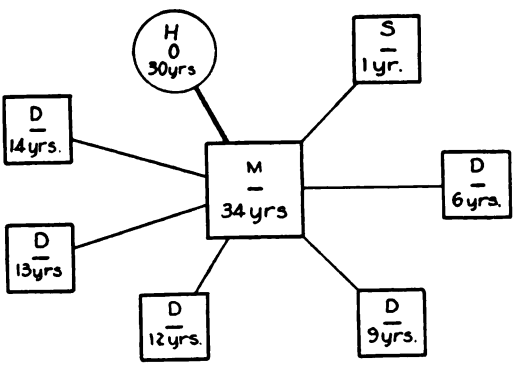
Ida D., daughter, 13 years, well-developed, well-nourished girl, negative to physical examination, and negative to the Von Pirquet test.

Gladys D., daughter, 12 years, well-developed, well-nourished girl, negative to physical examination and negative to the Von Pirquet test.

Ruth D., daughter, 9 years, well-developed, heavy girl, negative to physical examination and negative to the Von Pirquet test.

Artys D., daughter, 6 years, short, heavy girl, negative to physical examination and negative to the Von Pirquet test.

Arthur D., son, 1 year, heavy, well-developed baby, negative to physical examination and negative to the Von Pirquet test.



In this family of eight individuals, seven were examined and none showed evidence of tuberculous infection.

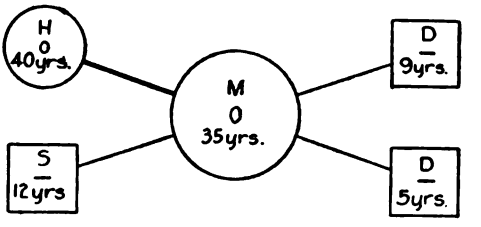
S. M. W. May 14, 1912.

This man and his wife were not examined as they are reliably reported non-tuberculous.

A. W., son, 12 years, is a large, very well-developed, well-nourished boy, negative to physical examination, and negative to the Von Pirquet test.

E. W., daughter, 9 years, tall, well-developed girl, negative to physical examination, and negative to the Von Pirquet test.

M. W., daughter, 5 years, well-developed, well-nourished girl, negative to physical examination, and negative to the Von Pirquet test.



In this family of five individuals, three were examined and none showed evidence of tuberculous infection.

H. G. L. July 10, 1912.

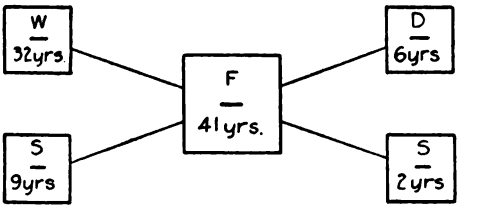
This man, 41 years, is negative to physical examination and negative to the Von Pirquet test.

Edith L., wife, 32 years, negative to examination and negative to the Von Pirquet test.

Laird L., son, 9 years, large, well-developed boy, negative to the Von Pirquet test, and negative to physical examination.

Elizabeth L., daughter, 6 years, tall, poorly nourished child, negative to physical examination, and negative to the Von Pirquet test.

Robert L., son, 2 years, small, poorly developed baby, negative to physical examination, and negative to the Von Pirquet test.



In this family of five individuals, all were examined and none showed evidence of tuberculous infection.

In thirty-three families classed as containing open cases of pulmonary tuberculosis, 173 individuals were examined. Of those examined, 124 individuals showed evidence of tuberculous infection, 41 showed no evidence of tuberculous infection, and 8 individuals were doubtful or suspicious. These suspicious cases were those which showed more or less signs of tuberculous infection but gave a negative Von Pirquet test; or not showing physical signs, gave an atypical reaction to the tests employed. All those classed as infected with tuberculosis gave a typical reaction to the tuberculin tests. Of the eight suspicious cases, one has since been declared tuberculous at the University Dispensary and one has had a pulmonary hemorrhage; both were adults and neither is included in the list of tuberculous infections.

Among the 124 showing evidence of tuberculous infection are the 23 living center cases. Deducting the 23 center cases, we have 101 individuals presumably infected from 33 open center cases, or 3 and $\frac{2}{33}$ for each case. Excluding the center cases, 67 per cent of the individuals exposed showed evidence of infection with the tubercle bacillus.

In four families classed as containing latent center cases, 22 individuals were examined. Of those examined 8 showed evidence of tuberculous infection and three were suspicious. Deducting the four center cases, we have a spread of infection in 22 per cent of individuals exposed.

In three families classed as containing healed center cases, 12 individuals were examined. Of the 12 examined, 6 showed evidence of tuberculous infection. Deducting the three center cases, we have a spread of infection in 33 per cent of the individuals exposed.

In ten families classed as containing non-tuberculous center cases, 56 individuals were examined. Of the 56 examined, one individual showed evidence of tuberculous infection and two were suspicious, an infection of 1.7 per cent of all individuals in the household.

In five families classed as controls and containing no reported or suspected cases of tuberculosis, 24 individuals were examined. Of those examined, one showed evidence of tuberculous infection, 4.1 per cent of all individuals in the household.

Dividing all families examined into two classes, tuberculous and non-tuberculous, there were forty tuberculous families and fifteen non-tuberculous families. In the forty tuberculous families 207 individuals were examined, of whom 138 individuals showed evidence of tuberculous infection. In the fifteen non-tuberculous families 80 individuals were examined, of whom two showed evidence of tuberculous infection and two were suspicious. That is, 66⅔ per cent of individuals examined in tuberculous families showed evidence of tuberculous infection, and 2½ per cent of the individuals examined in non-tuberculous families showed evidence of infection with tuberculosis.

Among the forty tuberculous families there are ten families containing

54 individuals, of whom every member was examined, and in which every member showed evidence of tuberculous infection.

Three families containing 12 members, of whom 7 were examined, showed evidence of tuberculous infection in all those examined.

In the latent group there was one family of seven individuals, of whom four were examined in whom no evidence of tuberculous infection could be found outside of the center case. Another latent case in a family of four showed only one individual infected, namely, the wife, and this probably a coincident infection as she had been otherwise exposed. No tubercle bacilli had ever been found in the sputum of this center case. In another latent case there were five children and the wife besides the center case, and only one child showed evidence of infection.

In another latent case where both husband and wife had been reported open cases there was but one child out of five who showed evidence of infection. One of the healed cases showed no spread of infection in a family of four. Another, where the mother is a healed case, shows two out of four children with evidence of tuberculous infection. In this case the history would indicate that the lesion had healed before the birth of the two immune children. In another case where the mother was diagnosed as an open case, her health greatly improved before the birth of her second child, the oldest child shows evidence of tuberculous infection and the two succeeding children do not.

The analysis of the non-tuberculous cases is simple. The one case of tuberculous infection found in the ten non-tuberculous families, which had been reported to the visiting nurses as tuberculous or suspected families, was the wife of a man who had been reported tuberculous and had been supervised for a number of years. He had at one time lost weight and at different times had hemorrhages, but no record of tubercle bacilli having been present in his sputum could be found. He showed no signs of a tuberculous lesion, and did not react to the tuberculin tests. The wife had not been a suspected case and showed no signs on physical examination, but reacted to the tuberculin tests. The family of seven children, five of them under six years of age, were without any indication of tuberculous infection. One other case with evidence of tuberculous infection occurred in one of my control families where no tuberculosis was suspected. The woman who showed evidence of tuberculous infection gives a history of having been in delicate health for two years during childhood. She has five healthy non-tuberculous children.

The following is a statement showing the percentages of tuberculous infections in thirty tuberculous families in which there were open cases, contrasting those supervised by visiting nurses with those not so supervised;

also between the cases not supervised and those supervised for different lengths of time. The time of supervision was obtained from the records of the visiting nurses of the Associated Charities, Minneapolis, Minn.

In eleven families supervised for less than one month, including all those not supervised at all, 55 people were examined. Of these, 43, or 78.2 per cent, showed evidence of tuberculous infection.

In nineteen families supervised for more than one month, 100 individuals were examined. Of these, 74, or 74 per cent, showed evidence of tuberculous infection. Average time of supervision, 12½ months.

In thirteen families supervised for more than six months, 74 individuals were examined. Of these, 54, or 73 per cent, showed evidence of tuberculous infection. Average time of supervision, 16½ months.

In six families supervised for more than one year, 24 individuals were examined. Of these, 16, or 66⅔ per cent, showed evidence of tuberculous infection. Average time of supervision, 26½ months.

In four families supervised for over two years, 17 people were examined. Of these, 12, or 70⅔ per cent, showed evidence of tuberculous infection. Average time of supervision, 32½ months.

I conclude from the above studies, first, that the spread of tuberculous infection in families where open cases of tuberculosis exist is greater than it is generally understood to be. Sixty-seven per cent of the individuals of these families, excluding the center cases, show evidence of tuberculous infection. In no case where there has been definite proven exposure of a family to an open case of tuberculosis, no matter what precautions have been taken, have I failed to find a spread of infection. In at least ten cases investigated, the infection has spread to the limit of available material. Every member of these ten families shows evidence of tuberculous infection.

Second, that in families where no cases of tuberculosis have been found, no matter what the home life or living conditions were, the number of individuals showing evidence of tuberculous infection was small, namely 2½ per cent.

Third, that in families where cases of latent tuberculosis exist, the spread of infection is not as great as in families where open cases of tuberculosis are found, 22 per cent against 67 per cent.

Fourth, that in families where healed cases of tuberculosis are present, the spread of infection is less than in families where open cases exist, 33 per cent against 67 per cent.

Fifth, that in families where no tuberculosis is found, the number of individuals showing evidence of infection is very small (2½ per cent) in comparison with the families in which open, latent, or healed tuberculosis exists.

The University of Minnesota

STUDIES IN THE BIOLOGICAL SCIENCES NUMBER 2

THE IMPORTANCE OF SEED CHARACTERISTICS IN THE NATURAL REPRODUCTION OF CONIFEROUS FORESTS

BY

JULIUS VALENTINE HOFMANN, M.F., Ph.D.

Special Lecturer on Sylviculture in the University of Minnesota

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PREFACE

Acknowledgment is made to Dr. F. E. Clements for assistance in planning the laboratory work and to Professor J. P. Wentling, under whom the sylvicultural work was done, for many suggestions in the development of the study and in the interpretation of the data. The author is indebted to the United States Forest Service for the investigations he conducted while at the Priest River and Wind River Experiment Stations, especially to Mr. D. R. Brewster for his help at the Priest River Experiment Station. All plates are original except Plates I and II, for which credit is given the United States Forest Service.

JULIUS V. HOFMANN

March 1, 1914

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THE IMPORTANCE OF SEED CHARACTERISTICS IN THE NATURAL REPRODUCTION OF CONIFEROUS FORESTS

Introduction

Almost all coniferous trees are dependent on seed for their perpetuation and distribution. Although in their natural state coniferous forests have maintained themselves and extended their boundaries with only minor or local changes of composition, this apparent equilibrium in nature is easily upset by man's exploitations, such as destructive lumbering, repeated fires, and unregulated grazing. The effort to find the cause for the ease with which this climax type of the plant kingdom is disturbed or entirely replaced led to a study of the seed.

This study has brought out many valuable facts about seed characteristics and their importance in the perpetuation and distribution of the forest. Seeds and their behavior have been studied in the laboratory and in the field with special emphasis on the importance of size, vitality, length of time required to germinate, and other characteristics.

Amount of Seed

The production of seed is an important factor in the perpetuation of the tree species, although the periodicity of seed years and quantity of seed produced by one species may vary widely from these same factors in another species. The variations of seed production of one species are often weighed against the same factors of another species, to advantage or disadvantage as the case may be. This appears to be true when associated species such as yellow pine (*Pinus ponderosa*) and lodgepole pine (*Pinus contorta*) or Douglas fir (*Pseudotsuga taxifolia*), hemlock (*Tsuga heterophylla*), western red cedar (*Thuya plicata*), and western white pine (*Pinus monticola*) are considered. The yellow pine is able to compete successfully with lodgepole pine under conditions favorable to the yellow pine. The lodgepole pine is, however, a much more prolific seeder, producing greater quantities of seed than does the yellow pine. What the lodgepole pine loses in ability to contend with unfavorable conditions, it gains in having many more seeds and consequently more seedlings with which to begin the struggle.

This is also true of the hemlock and its associates. If the enormous quantity of seed produced annually by the hemlock had the same chances of success as the species with which it associates, such as the Douglas fir, western white pine, and larch (*Larix occidentalis*), the entire forest would

soon be of hemlock. The small seed of the cedar is a good example. Although there is much seed of this species produced annually, the fact that it is small, produces a small seedling, and requires exceptionally favorable conditions for germination and establishment, limits the species and prevents it from getting entire possession of the ground.

In the Lake states, the jack pine (*Pinus divaricata*) produces many more seeds than the white pine (*Pinus strobus*) or the Norway pine (*Pinus resinosa*), and these species are always in keen competition with one another, resulting in the triumph of the jack pine in localities favorable to it.

Periodicity of the seed years is variable; so much so that it can not be considered in any practical application in planning for future forest work. It must, however, be considered in determining when the latest heavy crop of seed was produced. The forests produce seed sometimes annually and sometimes at periods of two or three years or even more. It is sufficient to know for the purposes of management, whether the latest crop was a sparse, medium, or heavy one.

In any average seed year, a forest furnishes enough seed to produce, under favorable conditions, an adequate stand of seedlings.[1] The heavy toll of rodents, fungi, drought, frost, and other unfavorable germination conditions, however, reduces the number of seedlings resulting from a single crop to a minimum.

In regard to seed production Darwin says: "Large numbers of seed are destroyed. The greater the chance against any given seed reaching a suitable locality and attaining maturity, the larger the number of seeds must the plant produce in order to maintain its numbers and as a general rule the smaller will the individual seeds be. On the contrary the greater the chance that each seed enjoys of arriving at maturity, the smaller the number of seeds that is necessary, and in such cases it is an advantage that the seeds should be large."

Distribution of Seed

Many species of coniferous trees bear seed with wings attached, being thus adapted for wind distribution. Most of the seeds have a wing attached to one side of the seed only. In an ordinary wind of ten or twelve miles an hour, such seed when released from the cone begins a downward spiral course and lands within 150 feet of the base of the tree. Since in a large part of our coniferous forests there is usually little wind in the autumn, or seeding time, wind can be considered a factor in seed distribution for only short distances from the seed trees. To be sure, the occasional blast of wind at the higher altitudes, blowing at the rate of seventy-five miles an hour, as has been measured by the writer in the Cascade

[1] Raphael Zon, Seed production of western white pine. *United States Department of Agriculture, Forest Service Bulletin* no. 210.

Mountains of Washington, may carry an occasional seed for a long distance, but satisfactory reproduction over large areas never results from a few seeds sown in this way.

Animals play a rather incidental part in seed distribution, and the carrying of seed by birds may account for the occasional trees found in unusual places. The most striking instance of animal distribution is seen in the yellow pine regions where squirrels, chipmunks, and mice collect and cache seeds and cones. Usually the caches are under logs, in stumps, or other hiding places. Often on the grassy slopes of the yellow pine region squirrels store separate cones under tufts of grass. The writer has examined and collected cones from such caches that covered areas 200 square feet or more. Mice also cache small piles of clean seed under grass tufts. Naturally rodents do not find all of the stored cones and seed, and in this way they become planters of seed even though they take heavy toll for their work. This accounts for the patches of yellow pine reproduction on some of the grassy slopes of western Montana and Idaho. Tufts of yellow pine have been found containing from ten to twenty seedlings.

METHODS OF STUDY

To determine seed distribution, belt transects 8¼ feet wide were run 2½ chains apart, covering 5 per cent of the total area, thus crossing it often enough to get representative areas under all conditions of moisture, shade, exposure (as to slope), and soil.

The belt transect shows the continuous conditions through the vegetation of a formation and gives graphically the relations of the various aspects and situations. It furnishes a record of the heterogeneity of the area in respect to species and soil conditions. The transect is preferable to the plot or quadrat in most instances, because the quadrat gives only a local record, and does not give topography and circumstances leading from one homogeneous formation to another.

Notes were taken on the kinds of soil, whether silt, sandy, rocky, clay, etc., vegetation cover, condition of soil, whether mineral or covered with humus, duff, or litter, and amount of charred logs and slash on the ground. Number and age of each species of seedlings present were recorded with conditions under which each individual or group of seedlings was found, as to soil, shade, or protection by logs or slash.

The following detailed report of an area studied in northern Idaho shows the methods used:

Designation..... Kaniksu-Fidelity Lumber Co., March 18, 1907.
Location..... Sec. 26, T. 57N., R. 5W., Boise M.
Topography..... Rolling, traversed by Pine Creek—a non-drivable stream—and the West Branch River—a drivable stream. Slopes and ravines shown by map.

PLATE I

The Migration Chart shows the area divided into units having similar factors influencing reproduction. These areas are designated by the letters of the alphabet. A letter appearing on two or three areas indicates that these areas are similar.

Areas A, B, C, and D are all within seed plots under about 50 per cent shade with sparse annuals and ground cover of duff, humus, and litter. The seed trees in the plots are healthy except in C and in the edge of D where they have been badly damaged by fire.

E is an area of unburned, partially piled slash on a steep north slope of 20 to 40 per cent, with scattered small trees of hemlock and cedar. The ground cover is of sparse annuals and patches of duff, humus, and litter.

F is an area of unburned, partially piled slash on a southeast slope of 15 to 20 per cent. The ground cover consists of scattered annuals, and a large per cent of the soil is covered with litter and duff. Scattered trees of hemlock and small cedar were left standing on this area.

G is practically level. The greater portion of it is unburned slash, partially piled, and the northern part of it has a pole stand of grand fir and cedar. The ground cover consists of a few annuals and litter and duff with some exposed places of mineral soil.

H is a south and west slope of 10 to 40 per cent, and is a very dry and hot situation. The north half of this area is covered with slash, piled but unburned. The ground is covered with scattering annuals and tufts of grass, except along the West Branch River where there is a heavy cover as previously described.

J is the general broadcast burned area of flat benches and slopes. The ground cover is described in the general description.

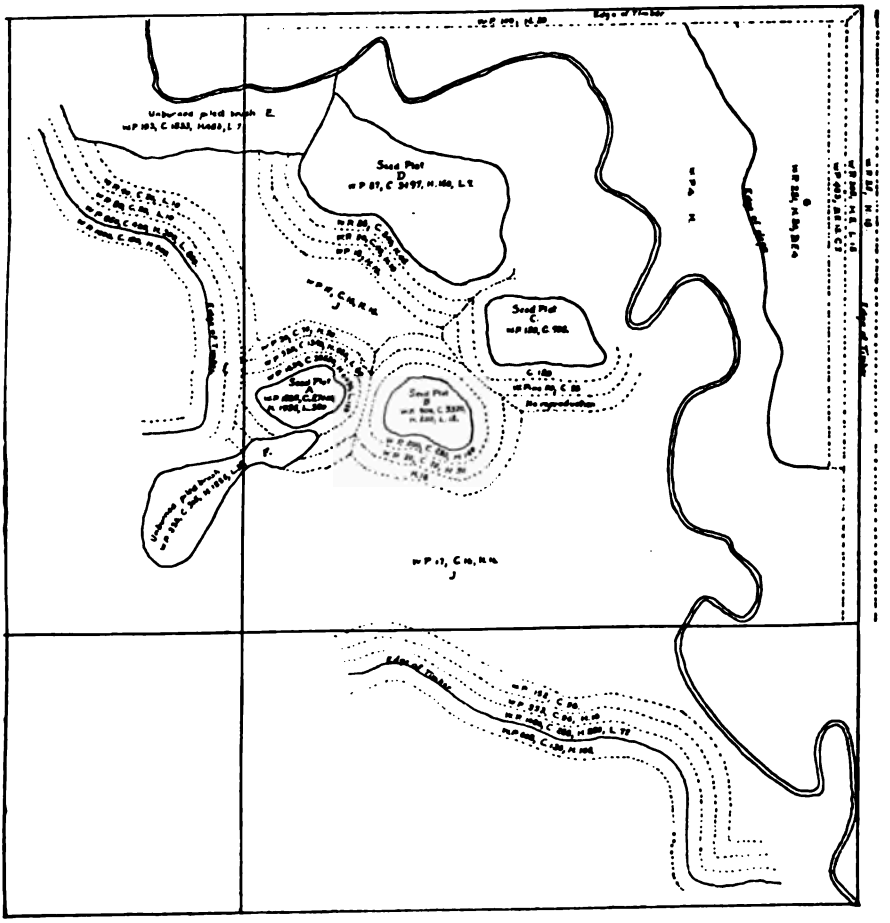

PLATE I

Showing the migration of the seed from the seed trees

Soil..... Silt and sandy loam, dry, gravelly on hillsides.
Condition before cutting. Forest mature and over-mature consisting of two-age classes of 100 years and 200 years. Considerable fungus and insect injury.

	White Pine	White Larch	Red Fir	Cedar	Cedar Poles
Average total height of trees (feet).....	140	140	120	120	75
Average diameter of trees (inches).....	20.1	20.4	20.4	27.0	12.8
Average number of trees per acre.....	27.4	3.7	0.8	2.8	17
Average stand feet B. M. per acre.....	17,564	2,068	358	2,496	545
Per cent of total stand.....	79	11	2.5	7.5	
Seedlings less than 5 feet high per acre—per cent of stand.....	30	10	10	50	
Trees between 5 feet high and 6 inches D.B.H. per acre.....	10	2.5	2	16	
Number trees over 6 inches D.B.H. to be left	4.5	1.5	0.5	5.2	

Reproduction..... Hemlock and cedar heavy throughout. White pine and larch in groups in openings.
Utilization..... All merchantable timber, living and dead, standing and down, cut.
Brush disposal..... All unmerchantable timber, slashed and broadcast, burned.
Burned-over..... June, 1910.
Seed years..... Good seed crop in 1909 and a fair crop in 1911.
Sylvicultural system.... Clear cut with seed plots.
Condition at time of examination, September 1912.

Ground cover. Scattering individuals of wild rose (*Rosa*), bearberry (*Arctostaphylos*), thimble berry (*Rubus*), Solomon's seal (*Polygonatum*), fern (*Pteris*), fireweed (*Epilobium*), mountain maple (*Acer*), willow (*Salix*), service-berry (*Amelanchier*), vetchling (*Lathyrus*), thistle (*Carduus*), horse-tail (*Equisetum*), lupine (*Lupinus*), alder (*Alnus*), goldenrod (*Solidago*), spiraea, lamb's quarters (*Chenopodium*), various kinds of grasses in tufts and heavy stands on river bottom flats, and clover (*Trifolium*) along the road sides, make a ground cover of about 50 per cent. This, however, is not an even cover as the vegetation is in groups with many open or sparsely covered areas.

The areas burned over are quite free from any material except some scattered charred logs. The mineral soil is exposed in some places and other areas are covered with humus and duff. Unburned strips covered with pine needles and wood litter occur along the timber. The soil has been in excellent condition for reproduction since the burn of 1910, and was in good condition at the time of the examination.

The cut-over area as a whole is naturally divided into units which have similar factors influencing reproduction, as seed-plots, slopes, slash, etc.

The Migration Chart shows that the reproduction is much heavier on all of the areas where the slash was left unburned. This is undoubtedly due to the seed and seedlings left on the ground at the time of cutting, as there are no seed trees in the vicinity of areas E, F, and G to reseed them. All of the burned areas adjoining have no reproduction. Areas E, F, and G have seed trees of cedar and hemlock, but no white pine.

As shown by the Migration Chart, the distance of seeding from the seed trees seldom exceeds 2 chains.

Conditions where the seedlings were found were very similar to the conditions of the area in general, indicating that no seed had been sown on the areas farther than shown by the Migration Chart.

These points were borne out by several areas studied in this region. They were also verified by intensive studies on the Yacolt burn of 1902, now in the Columbia National Forest in Southern Washington. This burn covers over 600,000 acres, and areas of hundreds of acres have no green trees left.

The distance of seeding to produce an adequate stand of seedlings, 500 to 1,000 per acre, in the localities studied on the Yacolt burn was found to be 2 to 4 chains for Douglas fir, noble fir, and amabilis fir; 3 to 5 chains for hemlock, and cedar; and usually 2 chains for white pine.

Germination of Seed

The length of time the seeds of a species require for germination often determines the success or failure of that species on certain sites. On some sites germination conditions are favorable for only a short period, consequently in order to take advantage of such periods a seed must germinate quickly. Where seeds of western yellow pine germinate in eight to ten days, the seedlings have a decided advantage over the western white pine, which may take fifteen to twenty days or more to germinate under the same conditions. In situations where the conditions are favorable for only three or four weeks, the early germinating seed assures success to that species, while the seed which germinated slowly may be only beginning to grow when unfavorable conditions occur, with a consequent loss of all germinating seed which has not established its seedlings.

On the other hand, the habit of dormancy may prove advantageous to a species by preserving the seed until a favorable season stimulates it to growth. By the refusal to respond to the first short favorable period for germination, the following drought may be avoided. Seeds of this character are often early spring germinators after one, two, or even several seasons of storage. This characteristic has been found in western white pine, Douglas fir, sugar pine, incense cedar, and others. When these species were sown in the nursery or seed spotted in the field, the germination

continued over several seasons. Instances of field sowing of Douglas fir and sugar pine have been found where the results were considered a failure the first season after sowing, and some germination appeared the second season, while the third season produced a very satisfactory germination. While this may occur under favorable conditions of sowing, the length of the dormancy period in nature under an environment less favorable for germination is still further prolonged.

Size of Seed

That the early development of the seedling is dependent on the food stored in the endosperm of the seed was shown by tests of seed of western yellow pine, Douglas fir, western hemlock, and western red cedar, in sand, in soil to which nutrient solutions had been added, and in potting soil made up of leaf mold and sand. The following nutrient solution was used:

To each liter of water was added:

1. gram calcium nitrate
0.25 " potassium chloride
0.25 " magnesium sulphate
0.25 " acid potassium phosphate

The soil was moistened with this solution and always watered with the same solution.

The seeds germinated equally well under all conditions, but the differences were very soon noticeable after germination.

Seedlings germinated in the sand came above the ground and appeared as good as those grown in the potting soil or in the nutrient solution. When the seed-coats were shed, they began to fail and apparently were unable to get any nourishment, or at least not sufficient to make any growth. After the cotyledon stage, these seedlings did not appear healthy and many of them soon developed their winter or resting buds. The seedlings in the potting soil and in the nutrient solutions made good growth and did not develop any buds until they had passed through the regular growing period. Those grown in distilled water grew until the food contained in the seed was exhausted, and then died.

In this connection it was noted that the seedling growth the first season was directly proportional to the size of the seed. This fact gives species with large seeds an advantage over species with small seeds, for example, yellow pine seedlings would become established on dry sites where hemlock or cedar would fail. The yellow pine would be able to send down roots to the moist soil, due to the food stored in the seed, while the small-seeded species would have to depend on obtaining nourishment and moisture from the surface soil, and consequently fail. Table I shows the results of experiments with different depths of cover in loam soil to determine the influence of food stored in the endosperm.

PLATE II

View of Yacolt burn of 1902, on the Columbia National Forest in southern Washington, showing edge of the green timber at the extreme right of the view; no other green timber in sight. This is part of the area where the reproduction study was made. Looking northwest from Lookout Mountain.

PLATE II

TABLE I

Species	Depth of Cover—Inches	Per Cent Germinated	Per Cent Appeared above Ground
Pinus ponderosa.....	1	82	82
	2	83	74
	3	71	42
	4	36	0
Pseudotsuga taxifolia.....	½	93	93
	1	87	85
	1½	72	64
	2	67	50
	3	42	3
	4	17	0
Tsuga heterophylla.....	¼	96	96
	½	92	76
	¾	86	50
	1	64	5
	1¼	42	0
Thuya plicata.....	⅛	78	78
	¼	64	52
	½	42	24
	¾	25	4
	1	26	0
	1½	19	0

The above table shows that seedlings will grow up through soil a distance which is in direct relation to the size of the seed. The development of the seedlings showed that they will grow to a size which is in direct relation to the amount of nourishment stored in the seed. If the seedling can not reach the surface before the supply of nourishment in the seed is exhausted, it must die. On the other hand if it is able to get above the ground, even as a final effort, the cotyledons open up at once and turn green, enabling the seedling to obtain food through a new source, viz., the chlorophyll.

It follows from this that seed may often germinate when covered with litter and duff and the seedling may not reach the surface, on account of the size of seed involved. Here then the larger-seeded species has an advantage over the smaller-seeded species.

The occurrence of seedlings or trees of any species on any site indicates that the site is, to some extent at least, favorable to the species found there, but it does not show that any other species would not establish itself or develop well there if given an opportunity. It is frequently merely a question as to which species first gets possession of an area immediately after the virgin forest is removed, or which species first had the opportunity of migrating there. In other instances it is clearly a matter of competition between species as to their ability to withstand the conditions of the site involved.

As one looks at the peaceful forest one should remember that underneath the calm serenity of the scene there is a bitter struggle, a relentless internecine warfare between the trees already established there and those that are striving to enter from without.

Soil temperature, soil moisture, aeration, and light are among the ecological factors which determine the establishment of a forest and determine the types within a forest. A wide variation of any one of these factors on different sites does not mean that the varying factor is the one which determines the type. Other factors, varying less, but approaching nearer to the limit of favorable conditions would have a greater influence on the germination of the seed or the establishment of the seedling. All the factors must be taken into consideration, and also the limits of each under which the seedlings will grow. While the moisture in the soil in two different localities may be equal, the soil texture may have a decided influence on the availability of the moisture for plants; that is, there would be a decided difference in the wilting coefficient. The fact that the surface soil often dries out, while at a depth of about six inches moisture may be present on protected slopes and absent on exposed slopes, gives decided advantage to seedlings with deep roots formed early in their development. For this reason, yellow pine has an advantage over hemlock and its associates in the forests of western Montana and Idaho. For the same reason, Douglas fir is able to establish itself on the drier slopes of the Cascades, while hemlock and cedar fail. A south slope covered with yellow pine or Douglas fir, and a north slope covered with hemlock, white pine, cedar, and other species, does not mean that each of these species is in its optimum habitat. It is rather a question of competition between species and of establishment. Yellow pine would produce excellent forests on some of the slopes occupied by other species if it could establish itself there. It is, however, crowded out by the large number of seedlings of the other species. On the other hand, the hemlock and cedar do very well under the conditions of the south slopes wherever they can get sufficient moisture to establish themselves. The reason these species are not in mixture all through the forest is not due to a lack of seed or even to the germination of seeds on the different slopes. An example of this nature was noted by the writer where two types met on a ridge. The south slope was seeded with seed from species found on the north slope. Seedlings of hemlock and cedar and larch were found germinating along with those of Douglas fir and yellow pine in the spring of the year, but in the fall only some of the seedlings of yellow pine and Douglas fir were left. The seedlings of the other species were unable to live through the dry period of the summer, due to their small roots and their inability to reach the moist layer of soil below the dry surface before they perished. These conditions are repeated year 'er year, and yet the type remains unchanged. It is very noticeable

that, wherever a ravine or spring keeps a south slope moist, seedlings from the species of the north slope are found.

Different slopes often get about the same amount of precipitation, but there is such a marked difference in the evaporation that the exposed slopes dry out while the north and protected slopes remain moist.

The effect of site exposure is clearly shown by the following summary table of meteorological data gathered near the Wind River Experiment Station at a station on a south slope, at an elevation of 2,150 feet, one on a north slope at an elevation of 1,750 feet, and one on an intermediate flat at an elevation of 1,150 feet. All stations were in the same watershed and less than one-half mile apart.

The important features of these results are the marked differences in evaporation during the critical drought period. During August the evaporation from water surface on the south slope was 15.1 inches, while on the north slope it was only 1.8 inches, with a corresponding moisture content of the surface soil on the south slope of only 1.0 per cent, while the north slope contained 6.5 per cent. With this extreme dry surface soil on the south slope, there still remained 11.2 per cent of moisture at 6 inches deep and 10.4 per cent at 12 inches. This would support plant growth providing a large enough proportion of the absorbing root systems were contained in this layer of soil.

In the spring of 1913, 100 seed-spots of Douglas fir were sown on each of the sites, south slope, north slope, and flat, and 25 per cent of the spots on each site were protected by cone-shaped wire screens to prevent damage by rodents.

Three examinations were made. At the end of the season the seed-spots on the south slope had no seedlings, either in protected or unprotected spots, since all that germinated during the season died in the dry part of the summer. On the north slope the protected spots had an average of .69 seedlings per spot, and 44 per cent of the spots contained seedlings, while the unprotected spots averaged .25 seedlings per spot and 22 per cent of the spots had seedlings. On the north slope there was no loss of the total number germinated. On the flat the protected seed-spots averaged 2.85 seedlings per spot and 88 per cent of the spots had seedlings, while the unprotected spots averaged .31 seedlings per spot and 34 per cent of the spots contained seedlings. The loss of the total germination on the flat was 6 per cent.

In the spring of 1913, the following species were sown under wire screens on each site: Douglas fir, noble fir, western white pine, and western yellow pine. An area of about 16 square feet was sown to each species, one half of the area being put in as a regular seed-spot and the other half broadcasted without preparing the soil.

TABLE II

Summary of Meteorological Data of Stations on South Slope, North Slope, and Flat

Readings averaged by months

	April	May	June	July	Aug.	Sept.	Oct.
Maximum temperature surface soil							
South slope		82.0	113.0	109.2	129.4	101.5	79.5
North slope		71.0	81.5	77.2	82.4	63.5	61.7
Flat		80.0	109.5	117.5	139.2	93.0	69.5
Minimum temperature surface soil							
South slope		37.0	46.0	48.2	46.8	43.2	38.2
North slope		38.0	48.7	52.5	51.0	44.0	37.5
Flat		37.0	47.7	47.8	43.0	38.2	33.7
Set maximum temperature surface							
South slope	46.0	59.2	63.2	90.0	121.0	71.7	56.2
North slope	46.0	56.2	63.2	69.2	68.8	54.5	50.4
Flat	44.0	60.0	69.7	92.2	104.6	75.7	56.5
Soil temperature six inches deep							
South slope	45.0	51.6	60.5	67.5	73.4	60.5	52.2
North slope	43.0	49.7	58.6	61.2	63.4	53.2	50.0
Flat	45.0	54.4	62.7	68.2	72.4	55.9	49.0
Soil temperature twelve inches deep							
South slope	44.5	50.9	59.2	63.2	69.2	60.7	52.6
North slope	42.0	49.0	57.5	59.0	61.4	53.7	48.7
Flat	44.5	51.9	60.5	64.7	67.6	56.2	50.0
Air temperature							
South slope	43.0	60.0	55.0	79.0	82.0	68.0	52.7
North slope	46.0	62.0	61.0	75.0	75.0	64.0	51.5
Flat	44.0	62.0	62.0	80.0	84.0	72.0	55.2
Relative humidity							
South slope		63.2	81.7	41.5	35.7	43.7	74.2
North slope		68.4	75.5	45.2	42.6	52.5	75.0
Flat		64.6	75.7	32.5	30.8	41.0	68.0
Evaporation from water surface in inches							
South slope		4.2	4.9	4.4	15.1	4.0	2.7
North slope		2.0	1.6	0.9	1.8	0.7	0.9
Flat		3.4	3.8	3.0	6.0	2.4	1.3
Per cent of water content in surface soil							
South slope	31.8	22.7	22.2	9.9	1.0	24.8	25.6
North slope	29.1	29.8	23.2	15.3	6.5	27.4	35.3
Flat	23.3	29.3	35.5	15.9	2.3	31.1	30.6
Per cent of water content in soil six inches deep							
South slope	30.5	27.4	21.2	18.9	11.2	28.7	30.5
North slope	35.9	23.1	25.9	23.2	17.5	26.8	32.1
Flat	26.3	28.9	25.7	24.0	17.4	29.4	30.2
Per cent of water content in soil twelve inches deep							
South slope	31.5	25.9	19.3	21.1	10.4	27.6	31.8
North slope	27.5	26.0	26.7	23.0	19.4	18.9	32.1
Flat	28.4	25.1	26.2	23.4	21.1	30.2	30.7

The sowing failed on the south slope. A few seeds germinated, but the seedlings perished during the dry season. The noble fir did remarkably well on the north slope, and the Douglas fir and white pine did fairly well, but the yellow pine failed. There was no loss of the total number germinated.

On the flat the Douglas fir did very well and had a 15 per cent loss of the total germination. The noble fir did fairly well, with a loss of 30 per cent of the total germination. The white pine germinated very little and had a loss of 46 per cent of total germination, while the yellow pine germinated very little, and 15 per cent of the total germination died.

The conditions under which the seedlings become established are shown in the following average summary of four areas studied in northern Idaho.

TABLE III

CONDITIONS UNDER WHICH SEEDLINGS WERE FOUND ESTABLISHED IN NORTHERN IDAHO

	WHITE PINE PER CENT	CEDAR PER CENT	HEMLOCK PER CENT	LARCH PER CENT	GRAND FIR PER CENT
SOIL					
On humus.....	3	2	7	1	9
On duff.....	34	16	19	32	28
On wood litter..	25	22	58	17	8
On mineral soil..	38	60	16	50	55
PROTECTION					
In shade.....	21	54	64	22	15
Under logs.....	8	4	8	8	25
In open.....	71	42	28	70	60
AGE					
1 year old.....	37	74	87	25	2
2 years old.....	19	9	8	11	4
3 years old.....	34	16	4	55	35
4 years old.....	9	1	1	9	50
5 years old.....	1				9

In regard to the areas examined, the above tabulation shows that the white pine seedlings start about equally well on the duff, wood litter, and mineral soil, while the other species do not show any particular preference. In this study, moisture was found to be the controlling factor, and the other conditions recorded are usually favorable only where they produced better moisture conditions.

Effect of ground cover after burns or cuttings. An area was selected on a south slope at an elevation of 1,700 feet, where the ground cover of wild pea vine and brush was very dense. One square rod was denuded of all vegetation and the area beside it left untouched. Readings of air temperature at the height of the crowns of seedlings, and soil temperature at surface, 6 inches deep, and 12 inches deep were taken each week on the denuded area and in the adjoining area where the natural vegetable cover

was undisturbed. The object was to find the influence of ground cover following a burn or clearing. The results are summed up in Table IV.

TABLE IV

NATURAL COVER AND DENUDED AREAS

	MAY	JUNE	JULY	AUG.	SEPT.	OCT.
AIR TEMPERATURE						
Natural cover	60.8	59.2	70.7	86.6	72.0	55.7
Denuded	72.2	64.4	84.7	102.8	76.2	60.0
SOIL TEMPERATURE						
Natural cover, surface	55.6	56.0	62.7	73.4	63.5	56.2
Natural cover, 6 inches deep	52.2	55.2	60.5	68.4	61.0	54.5
Natural cover, 12 " "	50.9	55.0	60.0	66.4	60.6	54.5
Denuded surface	74.5	67.5	92.5	124.2	89.2	64.5
Denuded 6 inches deep	57.8	62.0	68.0	78.7	67.0	54.2
Denuded 12 " "	56.3	61.5	67.0	74.4	66.2	56.2
PER CENT SOIL MOISTURE CONTENT						
Natural cover surface	33.3	32.4	23.1	10.5	33.4	36.5
Natural cover, 6 inches deep	21.3	26.7	20.0	12.9	29.5	26.5
Natural cover, 12 " "	23.9	20.5	18.6	15.4	28.4	27.7
Denuded surface	11.0	10.2	4.1	1.0	12.7	18.4
Denuded 6 inches deep	26.7	24.1	22.5	17.5	24.2	29.0
Denuded 12 " "	23.2	25.7	21.1	19.8	27.2	29.2

* Air temperature taken at crown on one-year-old seedlings.

Table IV shows clearly the effect of evaporation from surface soil when denuded, also the greater per cent of soil moisture at the 6-inch and 12-inch depths as compared with these same depths in the area having the natural ground cover of wild pea vine and brush. Although the surface dried out on the denuded area, the 6-inch and 12-inch depths still contained more moisture than in the area of the natural cover, due to the moisture being taken out of the soil by the roots and evaporated from the leaves in the area under natural cover.

The hot, dry surface soil shown in Tables II and IV accounts for the loss of one-year-old seedlings on these exposed slopes, while the moist, cooler surface under plant cover gives the young seedlings protection. The greater amount of moisture in the 6-inch and 12-inch depths on the denuded area and exposed slopes also shows why seedlings with deep roots early in their development will succeed on such slopes.

The following plates show the size of seedlings of various species of conifers up to one year of age. As will be noticed in the plates, the size of the seed influences directly the size of the seedling in its early life.

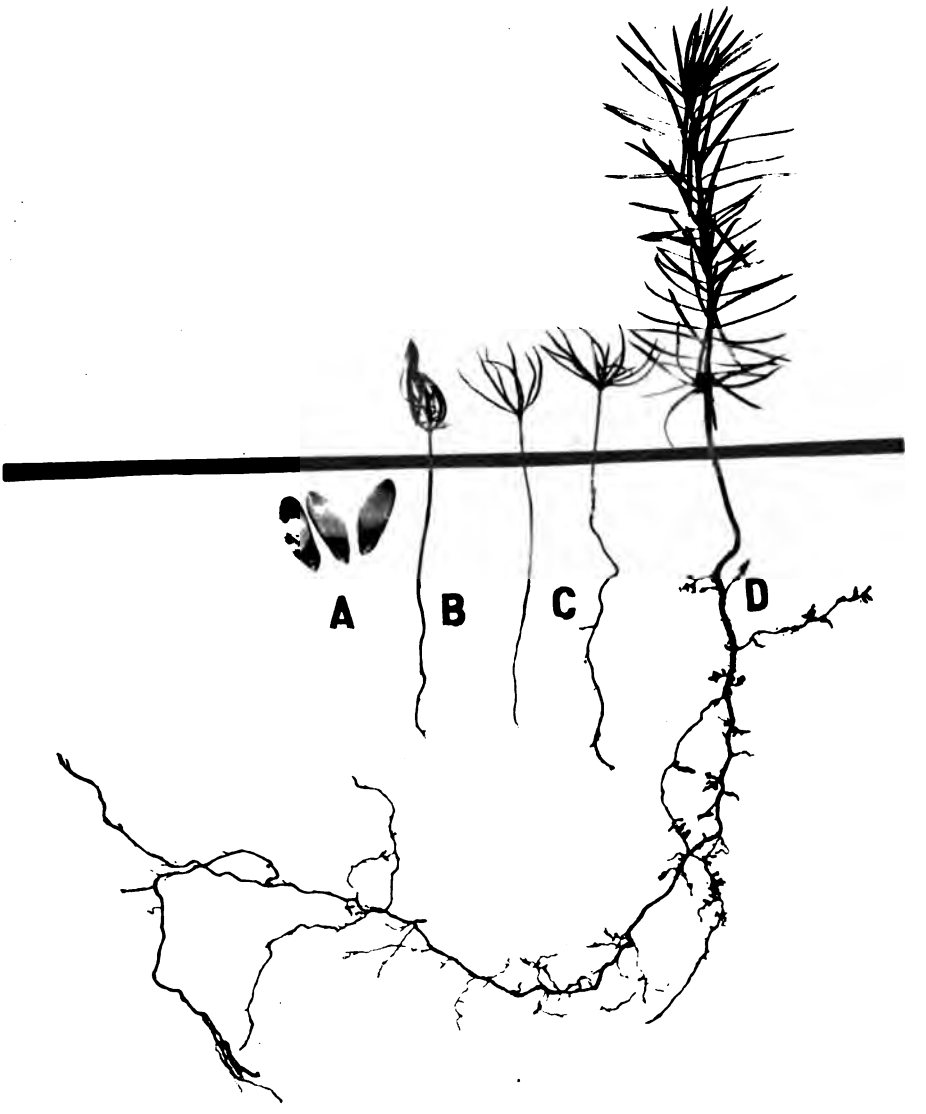

PLATE III

Pseudotsuga taxifolia
Douglas fir
(Size ⅔)

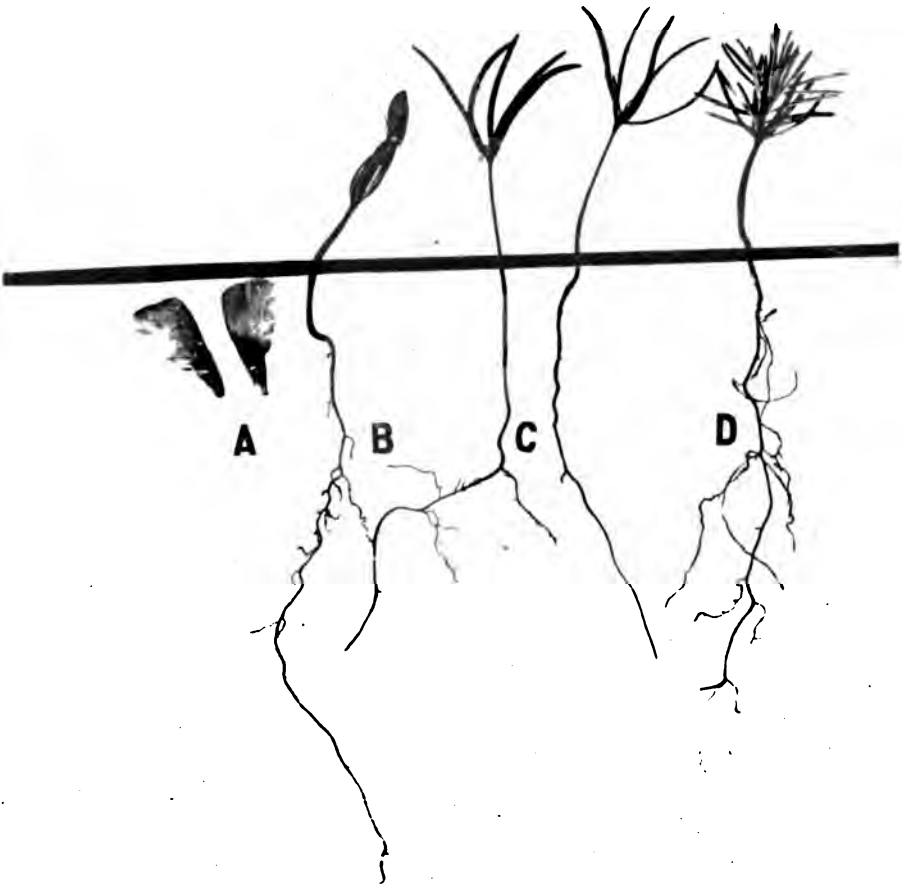

PLATE IV
Abies nobilis
Noble fir
(Size ½)

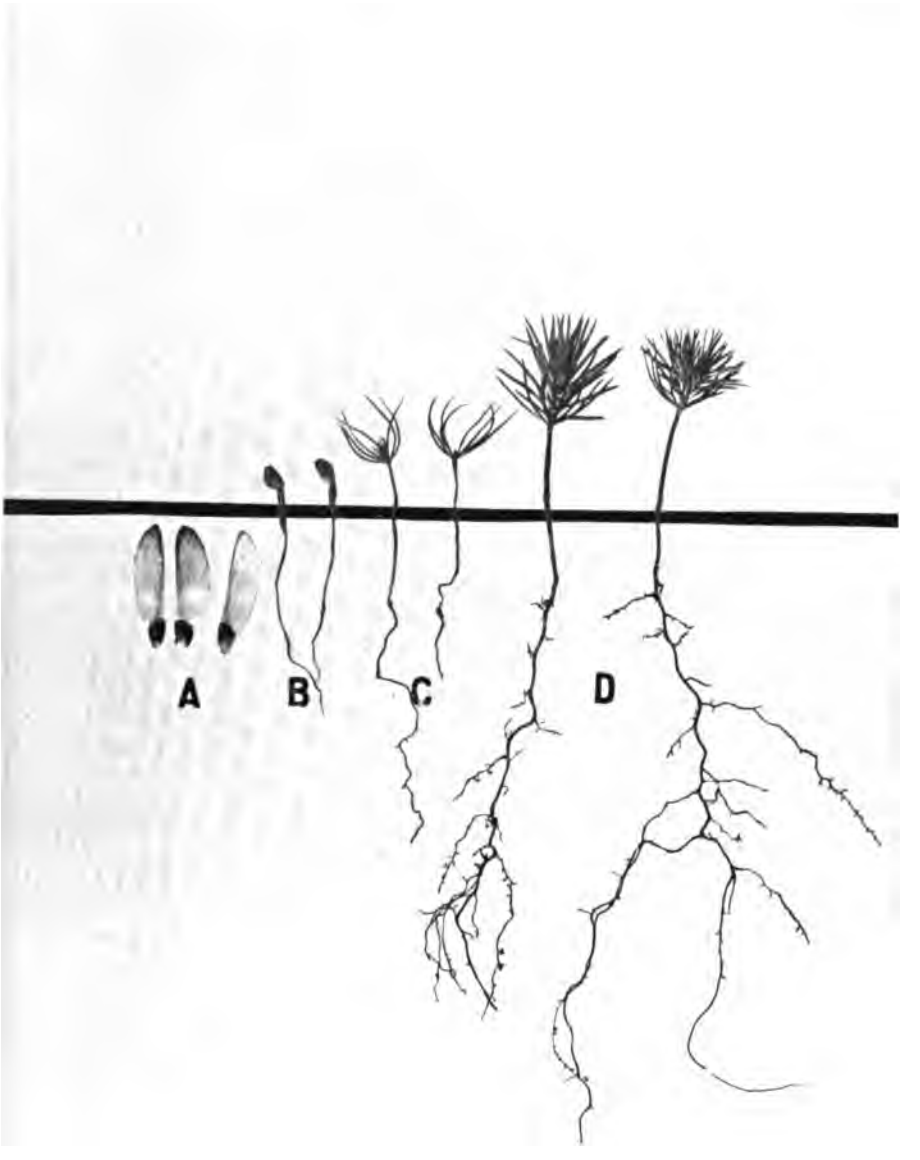

PLATE V

Pinus monticola
Western white pine
(Size ⅓)

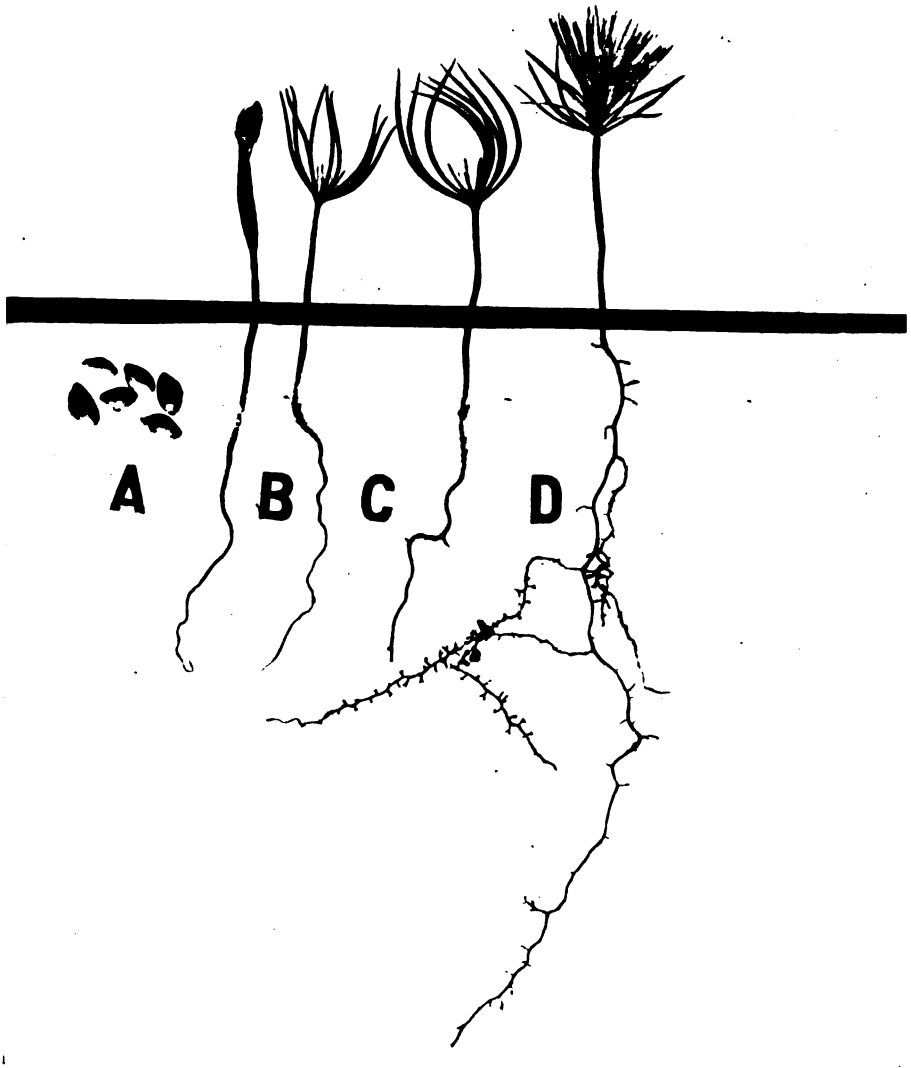

PLATE VI

Pinus strobus
Eastern white pine
(Size ⅝)

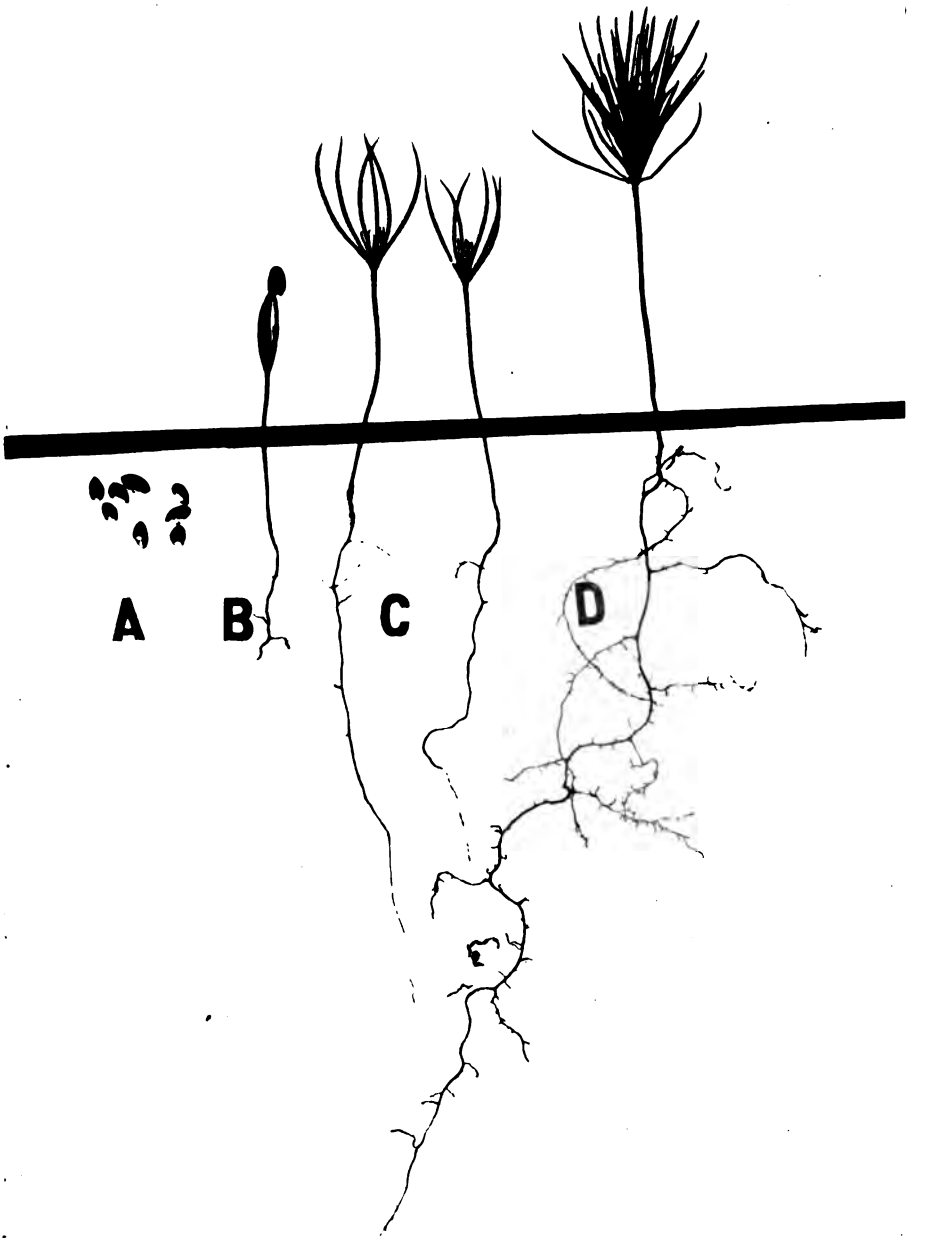

PLATE VII

Pinus resinosa
Norway pine
(Size ¾)

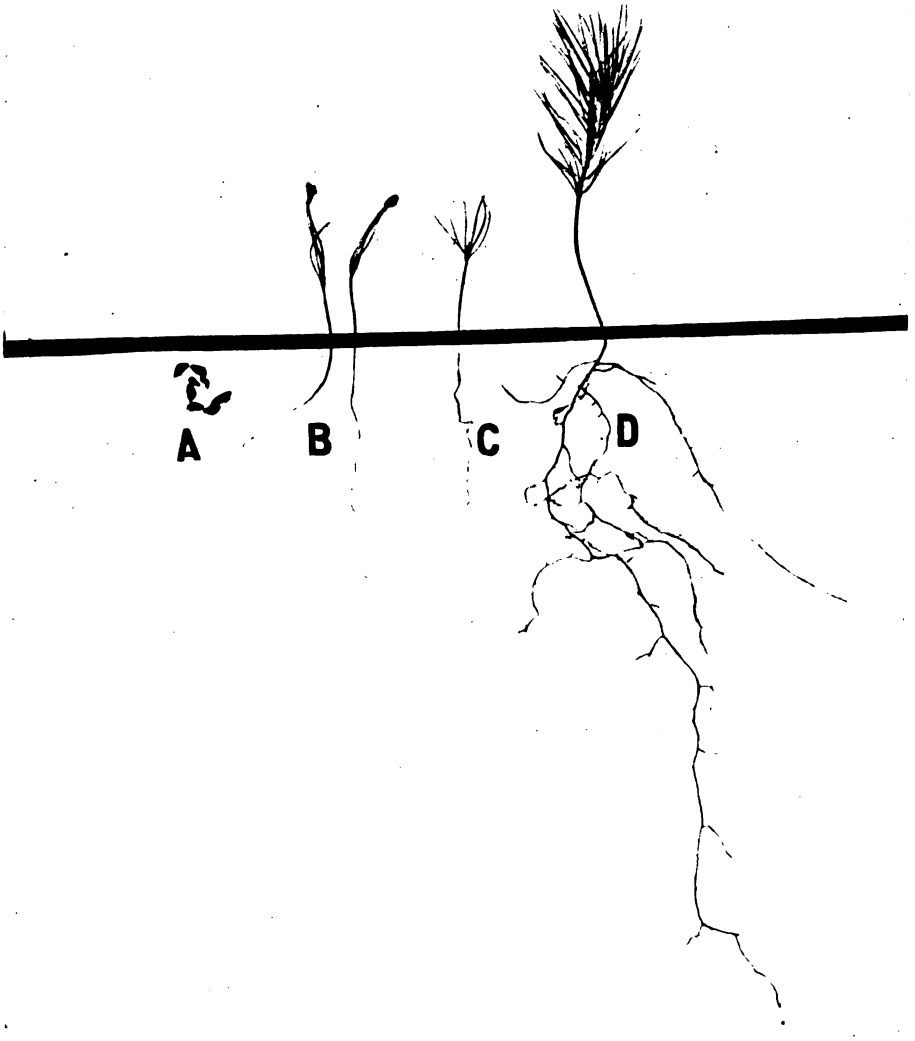

PLATE VIII
Pinus divaricata
Jack pine
(Size ⅝)

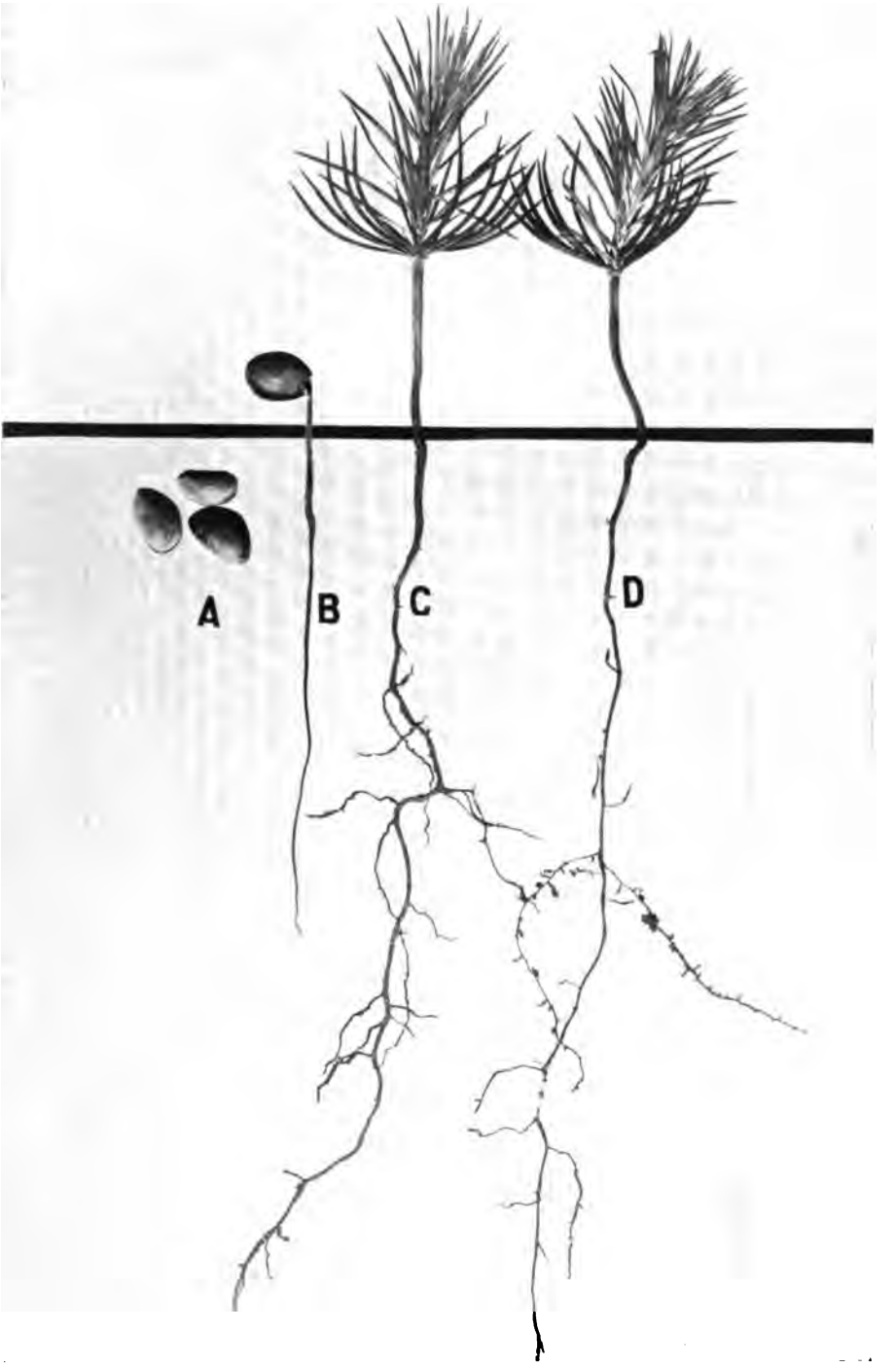

PLATE IX

Pinus lambertiana

Sugar pine

(Size ⅓)

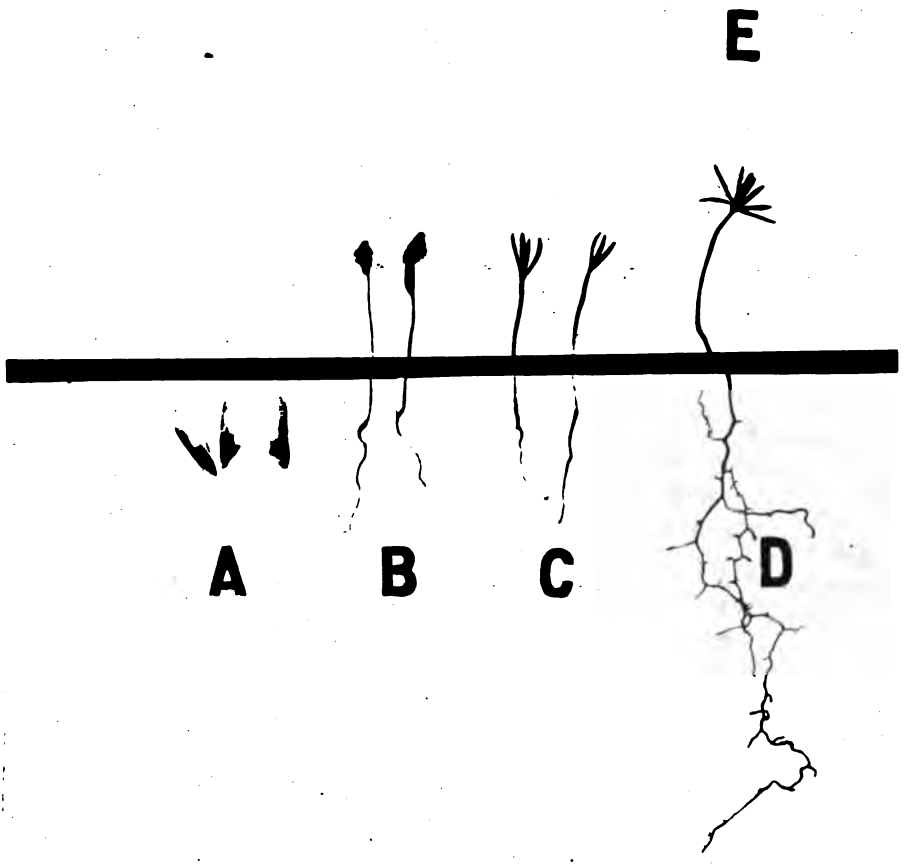

PLATE X

Tsuga mertensiana
Mountain hemlock
(Size ⅛)

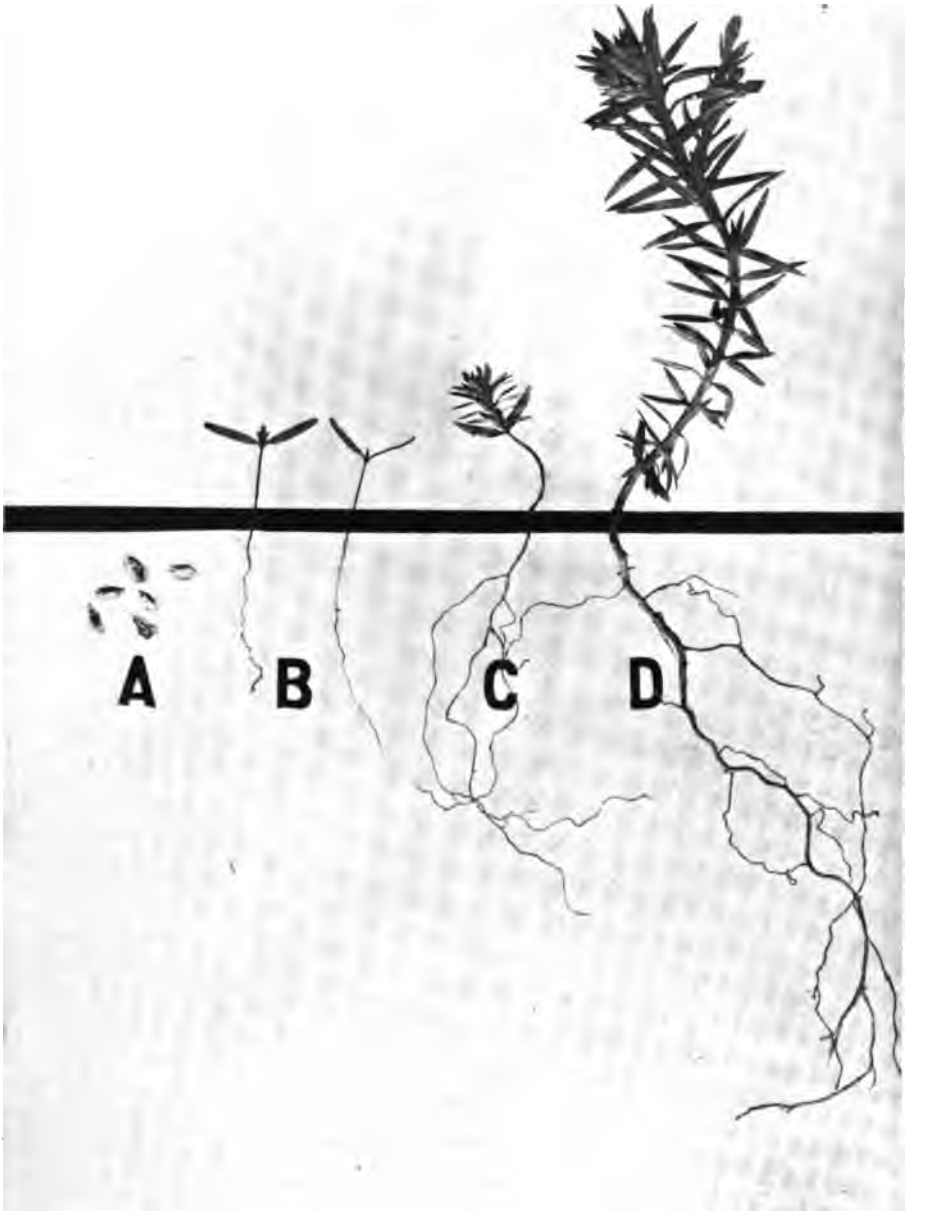

PLATE XI
Thuya plicata
Western red cedar
(Size ⅝)

DESCRIPTION OF PLATES

PLATE III

A. Seed. Color: light reddish to a dark brown and lustrous above, pale white mottled with brown below, smooth.
Size: 4–6 mm. long; 2.5–4 mm. wide at the widest point, tapering to a point opposite wing. Wings dark brown, 6–8 mm. long, 3–4 mm. wide at widest part just below the middle, tapering to a rounding apex.
Weight: average 35,000 seeds per pound.

B. Seedling as it appears above ground, about to shed seed-coat. Hypocotyl green to reddish tinge, cotyledons green.

C. Seedlings with cotyledons; green. Cotyledons 1.5–2.5 cm. long; linear tapering point; 6–9 in number.

D. Seedling one year old. Showing remarkable root system adapting it to the drier slopes and causing unusually fast growth.

PLATE IV

A. Seed. Color: pale reddish brown, slight tendency to be glossy. Wing very slightly lighter brown than the seed.
Size: 10–12 mm. long, 5–6 mm. wide at widest part near wing. Tapering to a point. Wing 10–15 mm. long, 12–15 mm. wide with widest part at top and forming a triangular shape with seed. Top also truncate.
Weight: 25,000 per pound.

B. Seedling as it appears above ground, about ready to shed seed-coat. Hypocotyl reddish green. Cotyledons green.

C. Seedlings in cotyledon stage. Cotyledons 2–3 cm. long, 4–7 in number, usually 6. Long slender, tapering point.

D. One-year-old seedling. A well developed plant.

PLATE V

A. Seed. Color: pale reddish brown, mottled with black.
Size: 5–7 mm. long, 4–5 mm. wide at widest part; oblong to triangular in shape. Wings light brown, 1.5–2.5 cm. long, 5–7 mm. wide at widest point, just above the middle. Rapid taper from widest point to a rounded apex.
Weight: average 30,000 seeds per pound.

B. Seedling as it appears above ground; green—sometimes pinkish, about to shed seed-coat.

C. Seedling with cotyledons. Cotyledons 2–2.5 cm. long, 6–9 in number, tapering point.

D. Seedlings one year old, showing strong root system enabling the seedling to establish itself. True leaves in bundles of 5 do not appear until second season.

Plate VI

A. Seed. Color: reddish brown, sometimes lighter brown mottled with black. Wings dark brown.
Size: 5–6 mm. long, 3–4 mm. wide at widest part, oval to triangular shaped. Wings 1–1.5 cm. long, 5–6 mm. wide just above seed and tapering gradually to an almost pointed apex.
Weight: 35,000 per pound.

B. Seedling as it appears above ground, about to shed seed-coat.

C. Seedlings with cotyledons. Stem pinkish green. Cotyledons 1.2–2 cm. long, linear with tapering point.

D. Seedling one year old. True leaves in bundles of 5 do not appear until second year. Seedling well established at end of first season.

Plate VII

A. Seed. Color: dull chestnut brown, mottled with grey. Wings lighter brown with strips of darker brown.
Size: 4–5 mm. long, 2.5–3 mm. wide, almost round and oblong. Wings 1–1.5 cm. long and .5–.7 cm. wide at widest part near middle, tapering to oblique rounded point.
Weight: 60,000 per pound.

B. Seedling as it appears above ground, about to shed seed-coat. Pinkish stem.

C. Seedling with cotyledons. Stem pinkish color. Cotyledons green, linear 2–2.5 cm. long tapering point. 5 to 7 in number, usually 6.

D. Seedling one year old, showing that it is well established at this age.

Plate VIII

A. Seed. Color: almost black, dull brown spots. Wings very light brown with darker brown stripes and margin.
Size: 4 mm. long, 2 mm. wide at widest part, triangular in shape. Wings 8 mm. to 1 cm. long, 3–4 mm. wide at widest part near middle, broad rounded apex.
Weight: 120,000 per pound.

B. Seedlings as they appear above ground, about to shed seed-coat. Hypocotyl pale pink.

C. Seedlings with cotyledons. Cotyledons 1.2–1.8 cm. long, narrow long tapering point, green. 4–7 in number.

D. Seedling one year old. Well established as shown by root system.

Plate IX

A. Seed. Color: dark brown, shiny on one side—side next to cone—and a greyish brown on other side. Wings dark brown.
Size: 1–1.5 cm. long, 1–1.2 cm. wide. Very thick, oblong to triangular shape. Wings 1.5–1.8 cm. long, 1.5 cm. wide. Widest at top with very slightly rounded top.
Weight: 2,370 per pound.

B. Germinated seed just as seed-coat pushes above ground, showing deep root developed.

C. and D. Seedlings one year old. Well developed root systems. Cotyledons 3.5–4 cm. long. Green, 12–16 in number, tapering point. Stem reddish green. True leaves in bundles of 5 do not appear until second season.

Plate X

A. Seed. Color: brown to deep reddish brown. Wings pale brown merging to a reddish brown where wing is attached to seed.
Size: 2 mm. wide, 5 mm. long, triangular shaped. Wing 5–6 mm. wide at widest part near top. 1 cm. long. About equal width throughout with broad rounded apex.
Weight: 260,000 per pound.

B. Seedlings as they appear above ground. Hypocotyl reddish tinge. Cotyledons pale green.

C. Seedlings with cotyledons. Cotyledons 4–5 mm. long, linear with short tapering points. Midrib not as distinctive as in *Tsuga heterophylla*. 3–5 in number, usually 3 or 4.

D. Seedling one year old.

Plate XI

A. Seed. Dry. Color: brown with lighter brown wings.
Size: 3 mm. long, narrow; wings 4 mm. long and 3 mm. wide including wings. Wings usually unequal, forming obcordate apex with seed.
Weight: 220,000 per pound.

B. Seedling with cotyledons. Hypocotyl pale pink color; cotyledons linear 6 mm. long, green, two in number.

C. Seedling one year old.

D. Seedling three years old. First true leaves forming. This shows that it takes the seedling a long time to establish itself and that it must have favorable conditions for more than one season.

A study of the foregoing plates will show the nature of the early development of these species. The noticeable thing is that the species which require the greatest amount of moisture are the ones in which the seedlings are slow in establishing themselves. The natural result of this is that these species are always found near the streams and on moist slopes. Cedar requires about three years to establish its seedlings, while a sugar pine or Douglas fir seedling is well established at the end of the first season. Hemlock is another example of a species with a small seedling during the first year, although it will produce a greater height growth than its associates after the seedling is established, that is, after the third or fourth year. It is clearly seen also that species which have large seeds establish their seedlings early, enabling them to live in places unfavorable to smaller-seeded species.

Viability of Seed

Seeds treated with chemicals

The following experiments for viability tests of the seed of *Pinus monticola* showed that the seed will stand rigorous treatment and still germinate. No attempt was made to duplicate conditions as they might exist in the litter and duff on the forest floor, but rather to test out the limit of endurance of the seed.

Copper acetate. Five treatments were given varying in strength from four ounces to thirty-two ounces of copper acetate per gallon of water in which the seed was soaked for two hours. Germination was not affected and gave the same results as the untreated plot.

Six treatments with strengths varying from two to four ounces per gallon of water in which the seed was soaked from twelve to twenty-four hours showed no effect on the germination. Traces of blue coloring in the endosperm of all of the treated seed showed that the solution had penetrated the seed-coats. This coloring was quite noticeable in the use of the stronger treatments. Some of the more strongly treated plots gave as good germination as those untreated, showing that the vitality of the seed was unimpaired. The seedlings that came up were thrifty and the root systems were well developed.

Zinc chloride. Eight treatments were used varying in strength from two ounces of zinc chloride to one gallon of water, up to sixty ounces of zinc chloride to one gallon of water. Seed soaked for two hours showed no effect on germination.

Four treatments, from ⅜ to one ounce of zinc chloride to one gallon of water applied to seed for thirty minutes, did not affect germination.

Ten treatments, varying from one part of zinc chloride to fifty parts of water by weight, up to one part zinc chloride to five hundred parts water; and ten treatments, varying from one part zinc chloride to three

parts of water by weight, to one part of zinc chloride to forty parts of water, all showed no influence on the germination. Zinc chloride has been found to be a stimulant to germination in the work done in soil treatment for fungi, and was expected to be a stimulant in germinating the white pine seed, but such did not prove to be the case.

Ether. Seven treatments of ether, varying from dipping to exposing the seed to the ether fumes for four hours, showed that the seeds were killed if left in the fumes for more than one hour. Liquid ether was put into a bottle and the seed suspended above it on a gauze, thus subjecting the seed to the ether fumes. The bottle was closed with an air-tight glass stopper.

Seed soaked in water. Seed was put into water at the following temperature in degrees Fahrenheit and left for forty hours: 100, 110, 120, 130, 140, 150, 160, 170, 180, 190, 200, 212. The temperature of the water was 65° to 70° F. when the seed was taken out. No germination was obtained above 150° F., but the seed soaked in 140° germinated 10 per cent as compared with 4 per cent in the unsoaked seed, showing that this temperature had stimulated germination.

Sulphuric acid. The following table shows the results of treatments of western white pine seed with sulphuric acid.

TABLE V

Treatment of Seed	Number Days before First Germination	Germination Per Cent 15 Days after First Germination in Series	Germination Per Cent 50 Days after Planting	Condition of Seed when Planted
Dipped A	23	2.8	4.0	Exocarp charred by acid
F-A-5	19	3.2	5.0	Exocarp charred by acid
F-A-10	26	1.6	3.2	Exocarp and mesocarp charred
F-A-15	19	1.6	3.2	Exocarp and mesocarp charred
F-A-30	23	1.2	3.0	Exocarp and mesocarp charred
F-A-45	19	2.4	7.4	Exocarp nearly removed and mesocarp and endocarp charred
Untreated	26	1.0	2.0	Normal
Untreated	21	1.2	2.0	Normal
½-A-30	21	1.6	3.2	Not discolored, seedcoats intact
½-A-60	21	1.6	3.4	Not discolored, seedcoats intact
½-A-120	37	0.0	2.0	Not discolored, seedcoats intact
½-A-180	21	0.8	2.2	Not discolored, seedcoats intact

A = Commercial sulphuric acid.
F-A-5 = Seed soaked in acid, full strength, for 5 minutes, etc.
½-A = One-half strength acid, that is, equal parts with water.

PLATE XII

View on Oregon National Forest in northern Oregon showing the results of a second fire. This area was burned over in 1902 and followed by dense reproduction of Douglas fir, noble fir, hemlock, and cedar. The second fire ran through in 1909. Note that the second fire is not followed by reproduction.

PLATE XII

Commercial sulphuric acid chars the seed-coats as soon as the seed is immersed. Where the seeds were left for thirty minutes and more in the full strength acid, the seed-coats could all be removed by slightly rubbing the seed, thus leaving the endosperm naked. Even in this condition, the viability of the seed was unimpaired, and, as the table shows, the strongest treatment gave the best germination results.

Seed treated with half strength acid showed no appreciable effects upon the seeds or on the germination.

Germination in all of the plots was perfectly normal. Seedlings in all the treatments appeared healthy and thrifty. Seedlings in the plots treated with the full strength acid for the longer periods appeared above ground, bringing up the endosperm without the seed-coat, and in some cases the cotyledons grew out through the sides of the endosperm. Seedlings appearing in this way produced strong, vigorous plants however.

Seed that was soaked in C. P. sulphuric acid for one hour was covered with water after the acid was poured off. The reaction created a temperature of 168° F. The exocarp was charred and most of it destroyed by the acid. The mesocarp and endocarp were also charred so that they rubbed off easily, but the endosperm or food material of the seed was apparently uninjured. Some of the seed germinated. Seed soaked for more than one hour and treated with water failed to germinate.

Aside from the experiments made to test out what severe conditions seeds will withstand and still retain their viability, the following chemical experiments to determine influence on germination were done with the same species, *Pinus monticola.*

Copper sulphate. Ten treatments, varying from one part copper sulphate to one part of water by weight, up to one part copper sulphate to five and one-half parts of water, showed that germination was stimulated by the chemical. The seed-coats opened in a few days, but as soon as they separated the copper sulphate solution stained and killed the germinating seed.

Copper acetate. Ten treatments, varying from one part copper acetate to one part water by weight, to one part copper acetate to five and one-half parts of water, showed that germination was stimulated by the copper acetate, but the growing tips were killed as soon as they appeared. Chemical injury occurred in all of the strengths used. In the weaker treatments, the germinating tips were stained blue, and in the stronger treatments the entire endosperm and plumule were stained blue.

The above experiments show that the seed in the dormant state will withstand very severe conditions, but is quite easily killed after germination begins. The chemical condition of the forest floor may therefore influence the viability of the seed and also be a major factor in determining the length of the period through which the seed will lie dormant and retain its viability.

It is known that seeds of other plants are viable for long periods, and the writer has known wild oat seed (*Avena fatua*) to remain in soil for seven years and produce a good germination the year it was plowed up.

Becker[3] draws the conclusion that oxygen acts as a stimulant in seed germination, and many of the conditions under which the seed germinates or does not germinate seem to bear this out.

Hatfield's[3] work on the *Vitality of Seed* showed that the *Hibiscus militaris* germinated after ten years, Rocky Mountain columbine after six years, tobacco, verbenas, ageratum, after several years' storage.

Duval[4] found the following seeds germinated after being buried in layers of clay, not below the frost line, for three and a half years: *Trifolium pratense, Trifolium repens, Polygonum avariculare, Bursa pastoris, Anthemis cotula.* The soil was taken into the greenhouse and the seed germinated.

Beal[5] secured some germination from the following seeds after they had been stored in soil for twenty years: *Amaranthus retroflexus, Brassica nigra, Capsella, Bursa pastoris, Lepidium virginicum, Anthemis cotula, Malva rotundafolia, Rumex crispus, Verbascum thapsus, Stellaria media, Polygonum hydropiper.*

These experiments give some idea as to the viability of the seed of some of the common and well-known weeds. Most of these have seeds with very thin seed-coats that are easily soaked with water. It is very probable that seed of the conifers with more or less resinous seed-coats would remain viable for a longer period. The characteristics of some of the coniferous seeds are well known, such as the western white pine, Douglas fir, eastern white pine, and the junipers. The seeds of these will often not germinate for two or three years even under the best of conditions in the nursery. Certainly they will remain viable as long or even longer when in the forest floor under unfavorable germinating conditions, but at the same time under good storage conditions.

Conzet[6] showed that the seed of the Norway pine (*Pinus resinosa*) remained in the forest floor for three years and then produced good germination.

The results of the study of the Yacolt burn are a practical demonstration of the viability of coniferous tree seeds. The study showed that reproduction occurs over the entire burn. The seedlings which germinated from one to three years after the fire vary in density, regardless of the location of seed trees, while the seedlings germinating later than this

[3] H. Becker, Über die Keinung verschieden artiger Fruchte und Samen bei derselber Species. *Beihefte Botanisches Centralblatt* 29:21-143. 1912.

[3] T. D. Hatfield, Vitality of seed. *Garden and Forest* p. 297. 1897.

[4] Duval, in the *Botanical Gazette* 37:146-47. 1904.

[5] Beal, Vitality of seeds. *Botanical Gazette* 37:222. 1904.

[6] G. M. Conzet, A qualitative and quantitative study of the seed production and reproduction of Norway pine (*Pinus resinosa*). Master's thesis, the University of Minnesota. 1913.

are almost all in close proximity to seed trees. At a distance of one or two miles from seed trees, the reproduction was in many instances much more dense than it was near the trees, often reaching 20,000 to 30,000 seedlings per acre. The distance from the seed trees and the erratic occurrence of the dense stands of seedlings, sometimes near seed trees and sometimes at great distances from them, showed that the seed had not been blown in by the wind since the fire. The areas of dense stands of reproduction ending in very irregular edges, beyond which no reproduction occurred, were convincing evidence that the seed producing the stands was present before the fire. These irregular edges showed where the ground fire which consumed all the duff had died out. Where the duff was left unburned the reproduction occurred. In all cases where reproduction occurred in burns, the burned trees of the species comprising the reproduction were found in the immediate vicinity.

When the Yacolt fire occurred in the early part of September, 1902, all of the timber was killed and the seed of that year's crop was badly scorched or burned. This is shown by the fact that there were no unburned cones or cone scales present on the burned-over areas, while charred cones and cone scales, as well as seeds of all of the species burned, were found. Also in the places where the surface of the litter and duff was charred, but undisturbed since the fire, seeds were found buried in the duff, some of which still had perfect wings. These facts are further strengthened by the appearance of the clear-cut margins and abrupt endings of the areas of good reproduction where 30,000 or more seedlings per acre occur, showing that the seed was in the litter and duff, and lived through the fire. That a large per cent of this seed germinated during the first season is shown by the large percentage of eleven-year-old seedlings. The five to ten year age class showed the distribution of the seedlings that came from the seed which germinated some years after the fire. Those of the older age classes at great distances from the seed trees, undoubtedly came from the seed which had remained dormant in the litter or duff and escaped the fire, as usually no seedlings under five years of age were found in these localities. In the case of the western white pine, there were no seedlings under five years old found during the entire study, although older white pine seedlings were distributed over the entire area. This indicated that the white pine seeds remained viable for six years under the conditions to which they were exposed. White pine seeds were found in some of the charred cones and also some in the litter and duff, but these undoubtedly were killed by the fire or were not viable.

The fire advanced before a southeast wind and the effects of it are recorded in the sparse reproduction on the south and southeast slopes where the fire was hottest and where all of the litter and duff was burned. On these slopes there were no areas of reproduction, only occasional

scattered seedlings, showing that very little seed was left after the fire, while on the slopes not struck by the direct flames of the fire, reproduction occurs in very dense stands regardless of the distance from seed trees.

Reproduction was found at distances of one or two miles from the nearest seed trees. In the case of the white pine, there are no seed trees on the township that could have any influence whatever on the area over which the reproduction of this species extends. Without a doubt the seed was there before the fire passed over the area, and escaped destruction. This seed may have dropped from the trees the year previous to the fire or even earlier, as must be the case where heavy stands of reproduction appear during the first season following the fire, since a dense stand of reproduction is not due to a single crop of seed but rather to an accumulative crop of several years. If the seed produced the same year the fire passed over the area was not killed, this study shows that this seed must lie dormant in the forest floor for several years. The indications are that the white pine remained six years; Douglas fir, six years; noble fir, three years; amabilis fir, five years; hemlock, three years; and yew was found scattered over the typical slopes of this species, varying in years from eleven to three, showing that the seed remained dormant for eight years. The yew was a good index in accounting for the seed on the area, as there is no question about the wind distribution of the berry-like seed. The theory that animals carried the seed can not be accepted because the seedlings invariably appear among the burned snags of yew, whereas animal distribution would not be confined to these areas.

These conditions are duplicated on all of the burns gone over on the Snoqualmie National Forest in northern Washington and the Oregon National Forest in northern Oregon. The burns on these forests were not studied, but general observations indicated that the conditions were the same as those found on the Columbia. The noticeable feature here was the absolute lack of reproduction after a second fire except very near to seed trees. This fact shows that good and wide-spread reproduction following a first burn comes from seed stored in the forest floor, and can not be attributed to seed furnished by a few surviving trees. Single seed trees surviving a second fire never restock an area except in their immediate vicinity. If a few escaped trees could restock a burn they would also restock a second burn on the same area.

Summary and Conclusions

All forest tree species in forest stands produce sufficient seed to reëstablish their own type under favorable conditions, and a change of type or removal of a forest from any area once covered with a forest is due to other factors than production of seed.

Species producing large seeds produce comparatively few in number.

Seed distribution is one of the important factors controlling the establishment of a forest type.

In the white pine region of Idaho, reproduction by wind-blown seed can not be depended upon for more than 150 feet from the seed trees.

In the Douglas fir region of the Cascades along the Columbia River, reproduction by wind-blown seed of Douglas fir and its associates can not be depended upon for more than about 300 feet from the seed trees.

Germination conditions are often unfavorable in a shaded and cool forest floor, hence seed may lie dormant for long periods.

By the removal of a forest, germinating conditions are improved, and the dormant seed germinates.

Moisture is the chief factor in the establishment of the seedling, while temperature is often a more important factor in germination.

The size of the seedling during its early life is directly proportional to the size of the seed.

A seedling from a large seed becomes permanently established much earlier than a seedling grown from a small seed, hence the former is able to obtain and hold possession of the more unfavorable sites.

Seed is always present in the forest floor, generally covered with and mixed in a layer of litter and duff.

This seed is a source of reproduction following forest fires or logging operations.

Some seed while dormant will withstand severe conditions, as shown by chemical tests.

Coniferous seeds are known to be viable after two to eight years of storage in the forest floor.

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AN INVESTIGATION OF THE LOUSE PROBLEM

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AN INVESTIGATION OF THE LOUSE PROBLEM*

INTRODUCTION

In April, 1917, a committee, representing different departments of the University, was formed to stimulate research dealing with war problems. The subcommittee from the Medical School, at the suggestion of Professor Leonard G. Rowntree, submitted the louse problem as one which required further investigation. Accordingly, during the rest of 1917 and the early part of 1918, the question was investigated by the writers under a grant from the Research Fund of the Graduate School granted by the Regents of the University of Minnesota, but in March, 1918, at the request of Dr. Richard M. Pearce, the work was continued under the direction of the Division of Medicine and Related Science of the National Research Council. The National Research Council supplied funds for the continuation of the work, but the entire research was conducted by the authors as members of the University staff, a room and facilities being freely placed at our disposal. We wish to express our appreciation of the courtesies and assistance of Dr. Pearce and others in Washington, and our indebtedness to Dean R. W. Thatcher, Director of the Experiment Station, and to the University authorities for the privileges and coöperation they have granted us during the investigation.

In the conduct of these investigations, the entomological experiments including the laundering, fumigation, and the effects of different chemicals upon the insects have been conducted by Moore, and the chemical experiments, including the suggestion of certain of the chemicals and their synthesis where necessary, by Hirschfelder. The clinical studies were also conducted by Hirschfelder. After September 25, 1918, when Hirschfelder was called to the Chemical Warfare Service, Professor R. A. Gortner, Chief of the Division of Agricultural Biochemistry, assisted by the preparation of a few brominated compounds, and has also favored us with valuable advice throughout the investigation. Mr. S. A. Graham, of the Division of Entomology, assisted in the rearing of the lice during the earlier experiments, while Miss Anna Wentz took charge of this work in the later experiments. The willingness of both Mr. Graham and Miss Wentz to feed and care for the lice contributed largely to the success of the investigation. Another disagreeable task, that of collecting lice from the dirty garments of louse-infested individuals, was conscientiously carried out by Mr. John Burke, technical assistant in the Department of Medicine. Special credit is due to those persons who volunteered as subjects for the experiments

* Certain portions of this paper have appeared in the following publications: *Journal of Laboratory and Clinical Medicine* 3: no. 5, Feb. 1919; *Journal of American Medical Association* 71: 530-31, Aug. 17, 1918; *Ibid.* 71: 1481-82, Nov. 2, 1918; *Journal of Parasitology* 5: 61-68, Dec. 1918; *Archives of Internal Medicine* 23: 419-30.

dealing with the toxic effects of louse bites. To all who have thus helped in the investigation of this problem, we wish to express our indebtedness, and our appreciation of their assistance.

NATURE OF THE PROBLEM

The clothes louse (*Pediculus corporis*) commonly known as "gray backs," "crumps," or "cooties," has presented a most important problem in the present war. Altho hundreds of papers dealing with investigations of this problem have been printed since 1914, and innumerable methods have been tried out, lousiness is still prevalent in the armies. This condition is due not to any great resistance of the louse to ordinary measures of destruction, since there are many methods by which it may be destroyed, but rather to the inability to apply these treatments under the conditions of modern warfare. The problem, therefore, is not to find some chemical or other means of destroying lice, but rather to find some method which can be applied under the existing conditions. It is not sufficient to find simply a method of delousing, but what is required is the simplest, cheapest, and quickest method in order that with a very small amount of equipment a large number of men may be cleaned in a very short period of time. To protect men from reinfestation, a chemical is required which will not only kill lice, but will also retain its effectiveness for the longest period of time.

METHODS OF REARING LICE AND NOTES ON THEIR BIOLOGY

The primary object of this investigation was to study the possible methods of controlling lice, and hence only notes or general observations upon their biology are available. What few observations are here recorded are largely from data obtained by Miss Wentz while rearing large numbers of lice to be used for experimental purposes. Experiments designed to determine some point in the life history were often discontinued to supply lice for experiments concerning the toxicity of some chemical; hence full data upon some points were not obtained. Other workers have studied their biology more fully, and recently Nuttall[1] has gathered this information together into one paper. In some of the biological studies the lice were confined by one means or another to some portion of the body of the experimentor, thus producing conditions as nearly normal as possible. Such methods are necessary for accurate observations upon the life history, but since the present object was rather to study means of destruction, entailing the use of large numbers of lice, the incubator method of rearing them was found to give the best results. The following observations show how nearly incubator conditions correspond to more natural conditions of rearing lice.

[1] The Biology of Pediculus humanus. *Parasitology* 10:80-185. 1917.

REARING LICE UNDER INCUBATOR CONDITIONS

Methods of feeding.—The lice, after being collected, were placed on small woolen squares (1 cm. x 1 cm.) in a glass vial or an ordinary drinking glass, and kept in a small electric incubator heated by means of two small carbon bulbs. The lice were free to roam over this wool, upon which they laid their eggs.

The first problem presented was the discovery of a successful method of feeding the lice. Rabbits and guinea pigs were experimented with as hosts, by tying them to a dissecting board and shaving the hair off an area of about 5 to 6 cm. square. The lice were transferred upon the woolen squares to the bare skin of the animal, but in all cases they refused to feed. Noeller[2] claims that they will feed and breed successfully upon a pig; hence a small pig about two or three weeks old was obtained and tested in a similar manner to the rabbits and guinea pigs, but altho the lice attempted to puncture the skin, they did not succeed. Similar attempts to feed on the ear of the pig gave negative results. Nicolle, Blaizot, and Conseil[3] have experimented with the monkey as a host and find that altho the lice fed, they did not feed as well as on man. A monkey having been obtained and freed of its own parasites, an attempt was made to feed the clothes louse upon a shaved area in a manner similar to the experiments with the other animals. In this case the lice fed, but not as readily as upon human blood. Another difficulty encountered was that of securing the monkey tightly enough to prevent movements which would dislodge the lice. Owing to this difficulty and the fact that the lice did not appear to thrive on monkey blood, the monkey was finally abandoned as a source of food. In a few experiments an attempt was made to feed lice with citrated human blood enclosed in sausage skins, but this was unsuccessful. All these experiments having failed, feeding upon the human forearm was finally adopted. In the first experiments, the lice were carefully fed under a glass cover, but this was soon found to be an unnecessary precaution. During the first feeding in captivity, the lice were prone to wander away from the woolen squares, crawling about over the arm, but after being fed once or twice in this manner and being kept in the incubator between feedings, they lost this migratory impulse and as soon as the woolen pieces were placed upon the arm, moved down, fed, and then again traveled up onto the cloth. In this manner, pieces of cloth with as many as 4,000 lice have been fed on the forearm at one time without danger of the person becoming infested.

Among the persons who have fed the lice in these experiments, one person was particularly interesting, inasmuch as the lice refused to feed on his arm, merely wandering about for as long a period as one hour, after

[2] Beitrag zur Flecktyphus Uebertragung durch Läuse. *Berlin klin. Wochenschr.* 53:778-80. 1916. Abstract, *Review of Appl. Entom.* (series B) 5:33.

[3] Etiologie de la fièvre récurrente; son mode de transmission par le pou. *Ann. Inst. Pasteur* 27:204-25. 1913.

which they were transferred to another person and fed readily. Later attempts to feed the lice upon this first person were in general unsuccessful, altho occasionally a few lice were found to feed. No possible explanation of this aversion of the lice to feed upon this person was discovered, but there can be no doubt that for some reason he was objectionable to them. In other experiments it was found that the lice fed readily upon his brother.

During the earlier experiments the lice were fed but once a day and were kept in the incubator at 26°–28° C. between feedings. These conditions did not appear to be favorable and several supplies of lice died off, the males in all cases dying first, leaving females only which laid infertile eggs. Since this occurred three times and therefore can hardly be considered accidental, it would appear that the males were not able to withstand unfavorable conditions as successfully as the females. Two feedings a day were then adopted and the temperature of the incubator increased to 28°–32° C. and the relative humidity raised to 70–80 per cent, after which no further trouble was encountered. Under these favorable conditions, lice were reared in the incubator generation after generation, as many as five generations having been observed. Starting with as few as 20 lice they have increased under incubator conditions to 4,000 and would no doubt have reached a higher number if permitted.

Incubator conditions.—It has been previously mentioned that a temperature of 26°–28° C. did not prove favorable to the lice, while 28°–32° C. proved successful. Martini[4] has shown that when lice are placed upon a surface so heated that the temperature of different portions registers from 15°–35° C., the largest number of lice will congregate on the areas showing temperatures ranging from 28°–31° C.

A temperature above 32° C. has proved, in general, somewhat unfavorable to the active stages, but not to the eggs. Eggs easily withstand a temperature of 35° C., hatching in a shorter period of time at this higher temperature. A low relative humidity was found unfavorable to both the active stages and the eggs, the effect being more noticeable when the temperature was above 30° C. than at a lower temperature. Sixty to eighty per cent relative humidity was most favorable to development, while a higher relative humidity, 90 per cent or above, was injurious, in fact more injurious than a low relative humidity. In one test, a relative humidity of 68 per cent was recorded in the space between the skin and the undershirt. With too high a relative humidity, the faeces of the lice remained wet and were smeared over the walls and bottom of the container, while the lice which died under these conditions usually turned black. The right degree of humidity was maintained by placing a wet towel or a dish of wet sphagnum in the incubator. This additional moisture

[4] Zur Kenntnis des Verhaltens der Läuse gegenüber Wärme. *Zeitschr. für angewandte Entomologie* 4:34-70. 1917.

TABLE I

INCUBATION PERIOD OF EGGS

No. of eggs	Hatching occurred after days															Temperature (Centigrade)	Per cent hatched
	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		
50	..	..	..	..	..	..	..	11	17	6	7	1	..	..	..	26°–28°	84
36	..	..	..	..	..	..	..	..	2	8	1	12	2	1	1	26°–28°	75
15	..	..	..	..	..	..	..	1	..	..	..	1	2	2	..	26°–28°	40
22	..	..	..	..	..	..	..	..	..	1	3	1	1	..	..	26°–28°	27.2
27	..	..	..	..	..	..	..	..	..	1	4	1	..	..	..	26°–28°	22.2
36	..	..	..	..	..	..	..	..	4	4	2	1	..	..	..	26°–28°	30.5
42	..	..	..	..	..	8	15	6	4	..	..	..	..	..	..	28°–30°	78.5
65	..	..	..	..	2	12	30	9	7	..	..	..	..	..	..	28°–30°	90.8
48	..	..	..	4	15	17	11	..	..	..	..	..	..	..	..	30°–32°	98
66	2	..	38	11	..	..	..	..	..	..	..	..	..	..	..	26°–33°	77.3
67	1	1	24	8	..	..	..	..	..	..	..	..	..	..	..	26°–33°	50.7
67	..	2	20	9	..	..	..	..	..	..	..	..	..	..	..	26°–33°	46.2

was very necessary during the winter months, when the humidity of the laboratory was quite low, while during the summer only a small quantity of water was necessary. The need for these moist surfaces in the incubator may have been due to the type of incubator used, there being a constant circulation of air through a small opening near the bottom and a similar opening in the top. This tended to reduce the humidity.

An effort was made to determine the correct percentage of moisture favorable for development by placing the vials with the lice in closed containers with different dilutions of sulphuric acid, but since it was necessary to open the container twice daily at feeding time, it is doubtful if the humidity within the container could adjust itself quickly enough to give definite results; at least no definite data were obtained.

Life history under incubator conditions.—Observations upon the life history of the louse were made from time to time during the regular experiments, and the tables given are compiled from these data. The eggs required from 6 to 20 days to hatch; 6 to 9 days, or rather 8 to 9 days, representing the incubation period under favorable conditions of temperature and humidity, while under a lower temperature and less favorable conditions the time required was 13 to 20 days. (Table I.) The results under good incubator conditions compare favorably with the 6 to 8 days required for the hatching of the eggs kept near the human body in Nuttall's experiments.[5]

When fed twice daily, 25 young just hatched from the eggs were successfully reared to adults in 10 to 16 days, compared with the 14 to 23 days required under less favorable conditions. (Table II.) This period is somewhat longer than the 7 days obtained by Nuttall[6] with lice worn continuously. The difference represents the unfavorable influence upon the development of the louse of feedings 8 to 14 hours apart. This delay in development is not serious, since in the experiment all of the 25 lice were raised to maturity, with no more than customary attention. About one day was required between the last moult and the laying of the first eggs.

TABLE II

LENGTH OF INSTARS

No. of lice	1st moult after	2nd moult after	3rd moult after	Total from egg to adult	Temperature (centigrade)	Feeding
25	2–4 days	4–6 days	4–6 days	10–16 days	29°–32°	2 in 24 hrs.
46	4–8 days	.....	...		26°–29°	2 in 24 hrs.
26	.....	5–8 days	...	14–23 days	26°–29°	2 in 24 hrs.
18	.....	.....	5–7 days		27°–29°	2 in 24 hrs.

No data are available concerning the percentage of the different sexes, but general observations give the impression that females were more

[5] The Biology of Pediculus humanus.

[6] *Ibid.*

numerous than males. Data concerning the longevity of the adults are also incomplete. One female required 16 days from hatching until the first egg was laid, after which she lived 26 days, laying in all 80 eggs. In other experiments 40 and 41 days were noted as the total life of the lice from hatching to death; while not more than 4 eggs were laid in any one day by a single female. Here again are shown the results of irregular feeding periods, since Nuttall[7] obtained as high as 12 eggs in one day with an average of 9.7 eggs per day, the total egg production of one female, when kept continuously upon the human body, reaching 272 eggs. Under such conditions the lice feed many times a day and do not gorge themselves with blood as they do when fed twice daily; hence there is more room in their body for the development of the eggs.

Lice may lay eggs even when not kept in an incubator but the egg production diminishes greatly with the lower temperatures. Three sets, one in the incubator, one in the laboratory, and one in the basement, were kept for six days, the data being given in Table III. Eggs laid under such conditions may be fertile and will hatch in the incubator, but eggs laid in the incubator and kept in the basement at 17°–23° C. never hatched, altho they were observed for three or four months.

In general the eggs obtained under the artificial incubator conditions were fertile, but sometimes the percentage hatching ran very low, possibly in part due to infertile eggs and in part to unfavorable hatching conditions. (Table I.)

Changes in appearance following death.—One of the chief causes of death appears to be overfeeding following fasting. Lice may survive long periods without food if kept at a low temperature, while at higher temperatures this period is much reduced. Lice were collected from infested individuals and kept in a laboratory heated to 20° C. for various periods of time without feeding. One set left for 40 hours showed 1 had moulted, 4 eggs had been laid and 1 immature louse and 1 male were dead, while 5 females, 5 males and 10 immature lice fed readily. A second lot fasted for 58 hours, during which time 6 eggs were laid, 1 immature louse had died, while 8 immature lice, 8 males, and 7 females survived and fed. A third set left for 88 hours resulted in the death of 3 females, 4 males, and 8 immature lice, while only 3 females and 1 immature louse survived and fed. Six eggs were laid during the 88 hours.

TABLE III

INFLUENCE OF TEMPERATURE ON EGG PRODUCTION

Location	No. females	Temperature (Centigrade)	No. days	No. eggs laid	Average per female per day
In incubator.....	18	27°–31°	6	306	2.8
In laboratory.....	15	15°–27°	6	48	.53
In basement.....	15	17°–23°	6	5	.055

[7] *Ibid.*

Frequently after such a fast or even after one of 24 hours under incubator conditions, the lice during or shortly after feeding will turn bright red, the color even extending into the legs. Such lice always die within a few hours. When a louse feeds after fasting, it takes so much blood that the remains of its last meal are forced out of the intestine, together with considerable quantities of undigested blood. If lice are thus able to remove the remains of their last meal, they retain their normal color and do not die as a result of excessive feeding. In some lice, particularly when kept under dry conditions, the contents of the hind gut seem to harden, and are not readily forced out during feeding. It is such lice which during the feeding or shortly afterward turn red and later die. The cause of death appears to be the rupture of the intestine due to the large quantity of blood taken in, while the hind gut is plugged with the hardened remains of the previous meal.

Lice destroyed by many different methods turn red after death, but this redness appears different from that following overfeeding. Lice destroyed by most chemical means thus turn a red or reddish brown color, apparently because of the escape of the blood through the walls of the intestine. Possibly the walls of the intestine are weakened by an autolytic action of enzymes which have not been destroyed. Lice killed by boiling water, which destroys the enzymes, do not turn red after death, but on the other hand heat coagulates the proteins and the blood and may in this manner prevent the louse from turning red. Many lice, killed by a temperature of 45° C., which should coagulate the proteins, turn red or reddish brown. Lice dying with little or no food in their intestine do not turn red nor do lice turn red when killed by a slowly acting poison requiring 24 to 48 hours to kill. This may be due to the fact that in the presence of such a poison lice usually fail to feed.

In the presence of rapidly acting poisons all movements of the lice cease, producing what Nuttall[8] calls sham death; since if the lice are then removed from the presence of the poison they usually revive within 10 to 12 hours. This suspended animation, as will be shown later, appears to be due to the closing of the tracheae to keep out the poison, resulting in the lice becoming stupified from lack of oxygen. If exposed for a longer period to the action of the poison, they die and assume a reddish coloration.

PATHOLOGICAL EFFECTS OF THE BITE OF THE CLOTHES LOUSE

Observations of other workers.—Typhus fever, European relapsing fever, and more recently, trench fever have been shown to be carried by the clothes louse, while minor infective diseases, such as favus, pityriasis, and

[8] The Biology of Pediculus humanus.
Combating Lousiness among Soldiers and Civilians. *Parasitology* 10:411-586. 1918.

impetigo contagiosa are also known to be conveyed in a similar manner.[9] Prurigo, prurigo senilis, urticaria, and porrigo, all pathological conditions caused by lice, are grouped together by the Editor of the *British Medical Journal*[10] under the general term Pedicularia. Melanodermia may also appear in the vicinity of the bites. All of these conditions may be considered as secondary effects due to some organism transmitted from host to host by lice, or to the direct toxic effect at the site of the bite followed in some cases by scratching, causing a skin rash such as urticaria. Payne,[11] however, noted a rise in temperature apparently due to a general toxic effect of Phthirus pubis. It has been demonstrated experimentally that this insect causes maculae caeruleae, and Duguet[12] has shown that these spots may also be produced by the inoculation of that portion of the body of the louse in which the salivary glands are located. Jamieson[13] records two clinical observations of young persons infested with clothes lice having a temperature of 103° F. in one case, and 106.2 to 106.4° F. in the other case, in each of which the temperature returned to normal after the patient was bathed and freed of lice. Reviewing the literature dealing with the toxic effects of louse bites, Nuttall[14] sums up as follows: "Apart from the maculae, Phthirus, like P. humanus, fleas, and mosquitoes, may cause a febrile condition owing to skin irritation, altho this appears to be rare; with the removal of the lice, the fever promptly subsides."

General observations.—In view of the above statements, the following observations were both surprising and interesting. Following the failure, in the spring of 1917, to use animals as hosts, a person designated as A undertook to feed them on the forearm. Altho fed but once a day, a severe case of urticaria developed; hence other persons were given an opportunity of assisting in this work. Among those offering assistance at this time, were C and D, both subjects used in the later experiments. C fed the lice 2 or 3 times a week during this period, but D was used only 2 or 3 times in the entire period of 3 to 4 months. The work continued in this manner until August, 1917, during which time no one person fed the lice more than 3 times a week, and at no time were there more than 400 lice. A person designated as B then took up the work and continued it until December, 1917, during which time all the lice, not exceeding several hundred at any one time, were fed by the same person. No noticeable symptoms of

[9] The Part Played by Pediculus humanus in the Causation of Disease. *Parasitology* 10:43-79. 1917.

[10] Editorial, Pedicularia. *Brit. Med. Journ.* 2:1427. 1869.

[11] Maculae caeruleae and Other Symptoms Produced by Pediculi pubis. *Brit. Journ. Dermatol.* 2:209-12. 1890.

[12] Sur les taches bleues; leur production artificielle leur valeur séméiologique. *C. R. Soc. de Biol.* 32: 69-78. 1880.

Expérience et recherches nouvelles sur les taches bleues. *Ibid.* 34:617-22. 1882.

[13] On Some Rarer Effects of Pediculi. *Brit. Journ. Dermatol.* 1:321-27. 1888.

[14] The Part Played by Pediculus humanus in the Causation of Disease.

illness developed at this time. Work was temporarily discontinued from December, 1917 until March 12, 1918, when it was again started; B feeding the lice on the forearm twice daily. The number of the lice being small, not more than 50, the local irritation was reduced to a minimum, by changing the feeding area from one arm to another, and by washing the arm immediately after feeding with 95 per cent alcohol followed by an application of a mixture of ½ glycerine and ½ ammonia. During April, the number of lice increased, and the first signs of a possible intoxication due to their bites were noted. B described the symptoms as follows: very nervous, extremely tired with great drowsiness in the early afternoon, sleeplessness during part of the night, at least to some extent due to burning and itching of the arms. A steady, dull ache at the base of the skull, sometimes extending to the eyes, was experienced, accompanied by chills and aching as if coming down with an attack of "grippe." Apparently a fever developed, but since no temperature records were taken, this can not be substantiated. This feeling of fever lasted 3 days, during which time a rash similar to measles appeared over the shoulders, chest, and neck, lasting about one day. The illness occurred between April 15 and 30, but since it was not associated with the louse bites, the data are very meager. About April 20, due to B's illness, C undertook to feed the lice. Whereas B had started with a small number of lice which gradually increased, C started with from 700 to 800, and almost immediately a general tired feeling or aching similar to that experienced by B was noted. In the calf of the legs, along the shin bones, and the soles of the feet, particularly underneath the toes, this pain became sufficiently intense to interfere with sleep until late in the night. An irritable and pessimistic state of mind developed. May 7, an illness resulted, the symptoms being very similar to "grippe" but accompanied by a rash, over the shoulders and abdomen, similar to German measles. German measles being prevalent in the community at that time, the illness was considered to be this disease and after remaining in bed for several days, C returned to work and again took up the feeding of the lice.

The general symptoms previously noted again developed with increasing intensity, the number of lice having increased to about 1,200 by May 15. May 28, C was again ill and the family physician having been called diagnosed the illness as "grippe." The following day, a rash, quite typical of German measles, developed but other symptoms of measles were absent. The heart was normal, pulse about 90, temperature varying from 100° to 102° F. A blood count showed a normal number of leucocytes and red blood cells. A severe headache was experienced, accompanied by a general aching, often intense, in the joints. Dr. A. D. Hirschfelder saw the patient and considered that the illness was not German measles nor was it "grippe," but thought it might be trench fever. Glandular enlargement was absent

and no enlargement of the spleen was noted. Recovery was complete except for a general weak condition by June 4.

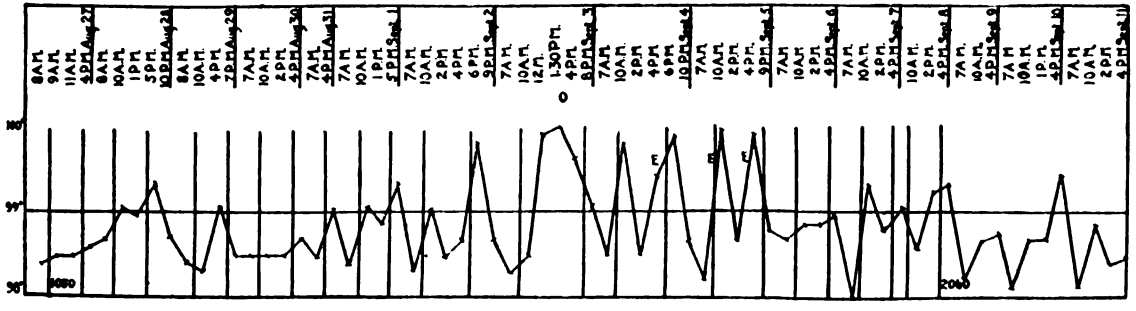
June 6, the lice, numbering about 800 adults, were again fed by C, but no symptoms of illness were manifest until about June 17 when the number of lice had increased to about 1,800, due to the hatching of young lice. Symptoms similar to the two previous illnesses then developed, but work was discontinued June 28 before they were serious enough to necessitate remaining in bed. The 29th and 30th were spent in the open and the symptoms gradually disappeared.

Clinical studies.—The observations given above indicate that a macular erythematous, skin eruption, somewhat resembling that of measles or German measles, distributed over the chest, back and abdomen, may occur in a normal individual who allows lice to feed upon the skin of the forearm only. This eruption was accompanied by general lassitude, headache, and peculiar pains in the calf of the legs and the soles of the feet, particularly under the toes. Unfortunately the association of these symptoms with louse bites was not at first considered; hence definite data of the illnesses are not available. A series of clinical studies was therefore planned at the suggestion of Major R. M. Pearce to determine whether the previously recorded observations represented a peculiarity of the individual upon whom the lice had fed, or whether it might be regarded as a general phenomenon. There naturally arose the question as to whether the condition represented sporadic typhus fever, trench fever, or some other infection, or a reaction to toxic products derived from the louse. Such a reaction might represent either a primary intoxication or a state of anaphylaxis, but in view of the fact that one of the individuals tested had never been bitten by lice before, the rôle of anaphylaxis seems unlikely. It is a striking fact, however, that in this individual none of the skin eruptions appeared. It is possible that the skin manifestations may represent an anaphylactic response, even if the general toxemia does not.

Four perfectly healthy young men, members of the Faculty of the Department of Agriculture of the University of Minnesota, volunteered for the experiments. They were examined by Dr. A. D. Hirschfelder and found to be normal, except, in some cases, for the enlargement of a lymph gland here and there. The total blood counts, haemoglobin, lymphocytes, and differential counts were taken and the two latter repeated daily or at frequent intervals. The Wasserman reaction was taken by Dr. W. P. Larson and found to be negative in each case.

The lice used in the experiments were raised from eggs and had been fed only upon the persons who were the subjects of these experiments and who were otherwise healthy, and upon one other perfectly healthy individual. According to the work of Strong and his collaborators[15] and

[15] Report of Progress of Trench Fever Investigation. *Journ. Amer. Med. Assn.* 70:1597-99.



Curve 1

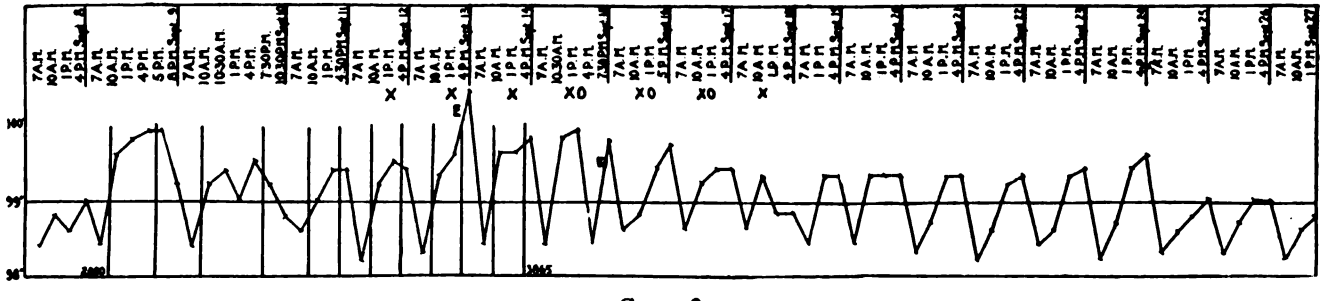
Rectal temperature of C. Vertical lines representing louse feedings, the number of lice being marked on the first and last lines. O represents the occurrence of a rash and E when exercise was taken. The line at 98. 95° denotes the average rectal temperature

Byam and his collaborators[16] these lice could not therefore be carriers of trench fever. No opportunity existed for inoculation with the faeces of the louse, since immediately after feeding, the arm was either carefully washed with soap and water and then bathed with alcohol, or was bathed with alcohol and then treated with ammonia and glycerin.

Experiment 1.—C, who had fed lice from time to time for the past year and a half and who had developed the symptoms noted above, started on August 27 the feeding of 1,050 lice twice a day. Health normal at this time. The rectal temperature remained normal until September 2, during which period the lice were slowly increasing in numbers. They failed to produce any reaction at the site of the bites other than a faint macular erythema, altho all the feedings were on the palmar surface of the left forearm. September 3 a faint rash, composed of semilunar and crescentic macules, 2 to 3 millimeters in size, resembling those of a fading measles or German measles occurred. More or less biparietal and vertical headache was present accompanied by a sort of dazed or confused sensation and a general lassitude. Blood cultures, aerobic and anaerobic, were negative. No enlargement of the glands or of the spleen could be detected. Following September 3, altho feedings were continued with an increasing number of lice until September 8, when they numbered 2,060, the fever diminished, but would always rise sharply following exercise even resulting from walking a few blocks. Discontinuing the feeding on September 8, the temperature returned permanently to normal. (Curve 1.)

Experiment 2.—A was the subject of the second experiment. Altho he had fed lice during the early experiments of 1917, he had not fed them since August, 1917. At that time no symptoms of illness were manifest but considerable local irritation had been experienced. September 9, the experiment was started with 2,000 lice. Considerable irritation resulted at the feeding site, an irregular red macular and maculo-papular eruption being present, a sharp rise in temperature following within an hour of the first feeding. On the fourth day, enlargement of the lymph glands of the axilla was noted and by the seventh day the inguinal and submaxillary glands also enlarged and became quite tender. A well-defined rash similar to that noted in the previous experiment was present over the chest, back, and particularly over the abdomen, lasting for three days. Blood cultures were negative. Feedings were discontinued on the 14th when the lice numbered 3,865. Altho the temperature diminished after feeding was discontinued, it was not until the 25th that it could be said to be normal. No general lassitude was experienced in this case, but the patient was weak and his mind confused during the period from September 12 to 18. Blood

[16] Trench Fever: A Report of Clinical Observations and Research as to the Etiology, Pathology, Prophylaxis and Treatment of Trench Fever among Troops. *Journ. Amer. Med. Assn.* 71:21-26; 110-13; 188-92.

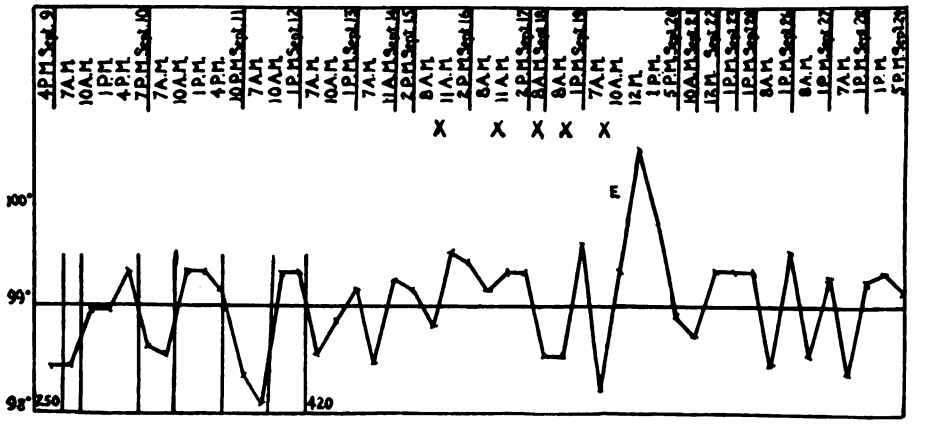


Curve 2

Rectal temperature of A. Markings same as in Curve 1 with the addition of an X to represent swollen glands

counts taken throughout the experiment failed to show any abnormal change. On September 27, after the temperature had been normal for three days, A started a canoe trip, during which fever was experienced, but having no thermometer, the exact temperature is not known. Immediately upon his return, 7:30 p.m., September 30, the temperature was taken and found to be 102.7° F. The lymphatic glands previously affected again became enlarged. For five days after his return his temperature remained at 100° to 101.7° F., during which time the swelling of the glands gradually subsided. His family physician, who had been called, found no symptoms other than a fever and the glandular enlargement. (Curve 2.)

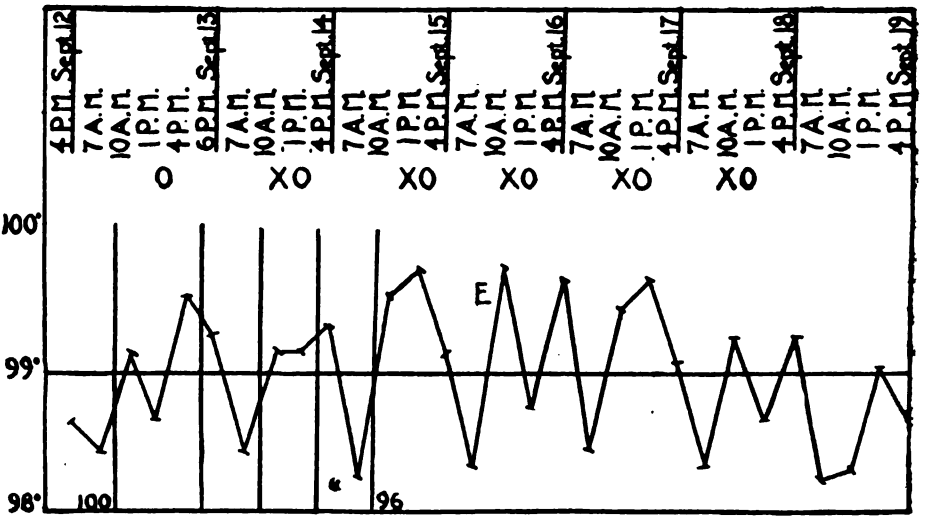
Experiment 3.—E, a person who had never previously fed lice, was the subject of the next experiment. Two hundred and fifty lice were used in this experiment. After two feedings a rise in temperature was experienced. Feedings were discontinued on the fourth day, when the lice numbered 420. His temperature, however, remained slightly above normal and glandular enlargement was noted on the seventh and eleventh days. Even slight exercise gave a decided increase in temperature similar to that noted in the previous experiments. No rash or other symptoms developed, and on the 19th, due to the development of a cold, the experiment was closed, although the temperature had not returned to what might be considered normal. (Curve 3.) In the case of E, faint, pink macules appeared at the site of the bite directly after feeding, but soon faded and after a few hours no evidence was apparent that the arm had ever been used to feed lice.



Curve 3
Rectal temperature of E. Markings same as in Curves 1 and 2

Experiment 4.—D, who had fed the lice a few times during the summer of 1917, was used in this experiment, the lice numbering 100 at the start

and 96 at the close of the experiment three days later. Immediately after the first feeding his temperature rose and within seven hours a rash, similar to that encountered in the previous experiments, was discernible. The following day glandular enlargement was noted, and by the following day the glands had become tender. Altho the feeding was continued for only three days, the rash lasted six days, the glandular enlargement five days, and seven days were required for the temperature to return to normal. (Curve 4.) Blood counts as in the previous experiments did not show abnormal numbers of either leucocytes or red blood cells.



Curve 4
Rectal temperature of D. Markings same as in Curves 1 and 3

Experiment 5.—F was injected subcutaneously under the arm with 3 c.c. of blood taken from A at the height of his illness. Within 48 hours, a definite rise in temperature to 99.5° accompanied by headache and a mild sore throat was experienced. Diffuse, small rales were present in his chest; but this reaction was probably due to an epidemic of "colds" prevalent at the time, rather than distinctly due to anything traceable directly or indirectly to the louse. The following day, his temperature was normal and remained so for the two weeks he was under observation. This phase of the subject needs further investigation, but due to the opening of college and to the epidemic of influenza, it was impossible to obtain more subjects for experimentation.

Except C, who may be considered to have developed a certain degree of immunity, every individual bitten showed a prompt rise in temperature shortly after the first feeding. The same individuals showed a well-defined

enlargement of certain of the lymph glands, while in three out of four of the subjects, a well-defined rash resembling fading measles or German measles occurred. The rash was not very striking and yet was definite enough to be seen without difficulty when it was at its height. The macules disappeared on pressure. They were distributed over the chest, back, and upper abdomen, and in no case appeared upon the face, neck, arms, or lower limbs. The rash was always most distinct and persisted longest in the region between the nipples and the lower costal margins.

In none of the individuals was the spleen palpable nor was its outline, determined by both light and auscultatory percussion, sufficiently enlarged to be definite. Aerobic and anaerobic blood cultures taken when the fever was at its height were negative.

The fact that the condition was produced by lice which had never bitten diseased individuals, and that no opportunity existed for inoculation with the faeces of the louse, as well as the negative character of the blood culture, point against either typhus or "trench fever." The absence of positive blood cultures, leucocytosis, and increases in polymorphonuclear leucocytes, as well as the absence of any foci of pyogenic infection at the site where the lice fed, rule out simple pyogenic infection.

The fact that two of the subjects, who had definite papular eruptions at the site of feeding, had also fed lice for a certain period of time a year before, while one person (E), who had never fed lice before, had no skin eruptions whatever, raises once more the question of anaphylaxis as a possible contributory factor in the symptom complex. That anaphylaxis was not the only factor, however, is proved by the fact that subject E, too, had fever and glandular enlargement as did the others.

While it can not be regarded as proved conclusively, the results of the above experiments point strongly toward the presence of a substance in the louse sufficiently toxic to give rise to a generalized skin eruption and mild fever. This may or may not be protein in nature. It is however quite clear that for the general health of the individual the bites of lice, even when "home grown," are not an indifferent matter, but greatly impair his health and bodily vigor. It becomes obvious from these experiments that men who are subject to louse bites have a lower mental and bodily vigor, and that other things being equal, a louse-free army would be considerably better fighting men than would the same army infested with lice.[17]

[17] Recently Dr. Walter C. Alvarez, of San Francisco, has communicated to us a case in which a man about 55 years of age, very heavily infested with Phthirus and Pediculus, was freed of his parasites in a county hospital. The patient at the time ran a low-grade fever, and after being cleaned, in spite of all efforts to build him up, died. An autopsy showed nothing to explain his decline and death, hence it may have been due to the toxic effect of the lice.

METHODS OF CONTROL OF THE CLOTHES LOUSE

Garment Disinfestation

Methods of controlling the clothes louse may be roughly divided into two main divisions; first, the destruction of the lice and their eggs in the clothing, and second, the destruction of the lice on the person and the protection of the individual from reinfestation. If the first method is thoroly and regularly carried out, and an effort is made to keep infested individuals segregated, the second method becomes unnecessary. Under the conditions existing in the present war, the regular and thoro disinfestation, or lousing, has not been possible. Not only did the men often go for long periods of time without an opportunity of bathing and having their clothing disinfested, but even when such an opportunity was offered, the time given to the work was generally too short to carry out a thoro disinfestation of all clothing. Such being the case, soldiers' garments coming to the laundry units near the front were often, if not always, infested with both lice and their eggs, and it became desirable to know the value of the ordinary steam laundry processes in garment disinfestation. The object of the laundry investigation was to determine to what extent these processes were destructive to both lice and eggs and, should they prove to be inefficient, what slight alterations could be made in the regular routine to make them effective.

LAUNDRY PROCESSES

Through the courtesy of Mr. J. Clair Stone, Manager of the Elk Laundry, Saint Paul, one of us (Moore) was able to study the processes encountered in the washing of regulation army clothing. The clothing may be divided into 3 types; rough cotton goods (including cotton underwear), cotton khaki wear, and woolen goods (including garments part wool and part cotton). Altho the procedure differs somewhat in different steam laundries, it may in general be outlined as follows:

COTTON GOODS

Baths	Temperature	Time (minutes)
1st water	100° F.(38° C.)	5
2nd neutral soap	180° F.(82° C.)	15
3d " "	180° F.(82° C.)	15
4th soda bath	130° F.(54° C.)	10
5th water	130° F.(54° C.)	5

Cotton goods are dried in the hot air tumbler at a temperature of 150° F. (65.5° C.) to 190° F. (87.7° C.) until quite dry. Time about 20 minutes, depending upon the load.

COTTON KHAKI

Baths	Temperature	Time (minutes)
1st water	100° F.(38° C.)	5
2nd neutral soap	120°–130° F.(49°–54° C.)	15–20
3d water	130° F.(54° C.)	5

Dried in the hot air tumbler at 150° F. (66° C.) to 180° F. (82° C.) until just sufficient moisture is left in the garment that it may be pressed. Time about 10 to 15 minutes, depending upon the size of the load. Pressed in the universal press.

WOOLEN GOODS

Baths	Temperature	Time (minutes)
1st neutral soap	110°–115° F.(43°–46° C.)	15
2nd water	110°–115° F.(43°–46° C.)	3

Woolens are dried at room temperature and never in the hot air tumbler.

The first important point to determine was what effect the temperature encountered would have upon the lice and nits. Data were available from the work of other investigations, giving an indication of what results might be expected. The following table was taken from a compilation of Nuttall:

IMMERSION OF EGGS IN HOT WATER

Temperature	Time	Result	Observer
192° F.(88° C.)	15 sec	Killed	Nuttall
169° F.(76° C.)	30 sec	"	"
158° F.(70° C.)	10 sec	"	"
150.5° F.(67° C.)	1 min	"	"
140° F.(60° C.)	5 min	"	"
140° F.(60° C.)	5 min	"	Widmann
131° F.(55° C.)	10 min	"	"
131° F.(55° C.)	30 min	"	Bacot
129° F.(54° C.)	10 min	"	Nuttall
121.5° F.(50° C.)	15 min	"	Widmann
112.5° F.(45° C.)	15 min	Not killed	"
104° F.(40° C.)	1 day	" "	"

EXPOSURE OF EGGS TO DRY HEAT

Temperature	Time	Result	Observer
124° F.(51.5° C.)	15 min	Not killed	Experiments of Capt. Orr, Canadian A. M. C., and Bacot
127° F.(53° C.)	15 min	Not killed	
130.5° F.(55° C.)	30 min	Killed	
132.5° F.(56° C.)	20 min	Killed	
134° F.(57° C.)	30 min	Killed	
152° F.(57° C.)	15 min	Killed	

Effect of laundry processes.—In my experiments it was found that the quantity of soap used varied somewhat, due to the hardness of the water. Sufficient soap was added to the water to give a good suds. It was found that with the water used in the experiments recorded below, 1 gram of ivory soap (neutral) and ⅛ gram of soda added to 265 c.c. of water furnished the desired suds. Inasmuch as the eggs are more difficult to destroy than the active stages, particular attention was paid to them. All the eggs were from lice collected from infested clothing, and kept in an incubator heated to 28°–32° C. The eggs were laid upon small squares of cloth during the week of July 27 to August 2 in Experiments 1–6 and from July 27 to August 7 in Experiments 7–12. Each piece of cloth therefore represented eggs in different degrees of development.

Exp. 1. Control set. 42 eggs. 78½ per cent hatched.

Exp. 2. Woolen goods treatment. Soaked in suds heated to 110°–114° F. (43°–45° C.) for 15 minutes. Rinsed in water of same temperature for 3 minutes, dried on a piece of filter paper and returned to the incubator. 65 eggs, 92 per cent hatched.

Exp. 3. Khaki wear treatment. Soaked in suds heated to 121°–126° F. (49°–52° C.). Avr. Temperature 123° F. (51° C.) for 15 minutes. Rinsed in water 123° F. (51° C.) for 4 minutes. Dried and returned to incubator. 38 eggs, 39 per cent hatched.

Exp. 4. Khaki wear treatment. Same as Exp. 3 except treatment was for 30 minutes. 45 eggs, 0 per cent hatched.

Exp. 5. Cotton goods treatment. Soaked in suds at 170°–186° F. (77°–86° C.). Avr. temperature 179° F. (82° C.) for 30 minutes. Rinsed in water 130° F. (54° C.) for 5 minutes. Dried and returned to incubator. 52 eggs, 0 per cent hatched.

The following experiments were conducted to determine the effect of treatment in the hot air tumbler and pressing in the universal press upon the eggs of the louse.

Exp. 6. Eggs placed in pocket of a bathrobe in the hot air tumbler carrying a heavy load. Tumbler had been running for 5 minutes before eggs were placed in it. Eggs in the tumbler for 10 minutes and garments were quite moist when eggs were removed. Eggs replaced in incubator after treatment. 88 eggs. 0 per cent hatched.

Exp. 7. Control 48 eggs. 100 per cent hatched.

Exp. 8. Cloth upon which the eggs were laid wet and then placed in the pocket of a pair of khaki trousers which was tumbled with other garments for 15 minutes. Load light and removed while still damp. Regular practice of drying khaki wear. 146 eggs. 0 per cent hatched.

Exp. 9. Eggs placed in pocket of partly dried bathrobe. Light load of clothing, tumbled for 10 minutes. 53 eggs. 0 per cent hatched.

Exp. 10. Same as Exp. 9 but tumbled for 15 minutes; 73 eggs. 0 per cent hatched.

Exp. 11. Same as Exp. 10, but tumbled for 20 minutes; clothing quite dry when removed. Regular cotton goods treatment. 57 eggs. 0 per cent hatched.

Exp. 12. Cloth with eggs placed under pocket of a pair of khaki trousers being pressed in the universal press. After treatment removed to incubator. 61 eggs. 0 per cent hatched.

The recorded experiments on the effect of soap suds at different temperatures on the eggs of the lice would lead one to suppose that active stages would also be destroyed in those experiments where the suds had proved destructive to the eggs. To verify this, the following experiments were conducted:

Exp. 13. Twelve recently fed lice in different stages of development were dipped in suds at 110°–114° F. (43°–45° C.) for 15 minutes, rinsed in water at 112° F. (44° C.) and dried on filter paper. All revived within a few hours.

Exp. 14. Same as Exp. 13, but suds at 122–126° F. (50–52° C.). Avr. temperature 124° F. (51.1° C.) for 15 minutes. All lice killed by treatment, turning reddish brown within 5 hours.

Exp. 15. Same as Exp. 14 but exposure lasting 30 minutes. All lice killed.

The experiments show that the washing of rough cotton goods at 180° F. (82° C.) for 15 or 30 minutes will destroy the lice and their eggs. If by any chance an egg should escape destruction in the washing process it would later be destroyed during drying in the hot air tumbler. Washing cotton

khaki clothing at a temperature of 120°–130° F. (49°–54° C.) for 15 minutes would prove destructive to the active stages, but would not completely destroy the eggs. Washing for 30 minutes, however, proved destructive to the eggs. Drying khaki uniforms in the hot air tumbler would also destroy any eggs that might have escaped the action of the hot suds. Pressing in the universal press was also effective, but this treatment can not be relied upon to destroy all the eggs in an infested suit, as portions of the uniform may not be touched. Neither the lice nor their eggs were destroyed in the woolen goods by the regular washing, and since they are dried at room temperature, the problem resolved itself into devising some method of laundering woolens that would prove destructive. The first method which suggested itself was the treatment of the woolen goods in the hot air tumbler for 10 to 15 minutes before they are washed and while still dry. Nuttall[18] claims "that the moderate degree of dry heat necessary to kill vermin will not prove injurious to wool but that high temperature, 104° C., acting for 4 hours while but slightly yellowing white flannel, does not affect its tensile strength, but if exposed to 127° C. for half an hour, flannel yellows and becomes brittle." This method, however, is open to two objections; namely, the danger of reinfestation of clean garments from handling garments infested with active stages in the vicinity of the tumbler, and the coagulating effect of the hot air on stains of blood, excreta, and other proteins, which may be present on garments before they are washed. Both these objections would be removed if the garments were first washed in such a manner as to destroy the active stages. The garments after drying could then be run in the tumbler to destroy all eggs which had escaped destruction during the washing.

The effect of soap suds on lice.—In experiments on contact insecticides, Moore and Graham[19] had found that, where the insecticide possessed both wetting and spreading properties, it entered the tracheae of the insect, thus bringing about death. Fat solvents, oils, etc., together with soap, possessed such properties. Ivory soap, however, was found to possess great cohesion, thus preventing it from readily entering the tracheae. By raising the temperature of the solution or diluting it with water, the cohesion was reduced. From these results, it was not apparent why the suds used in the previous experiments at a temperature of 110°–114° F. (43°–45° C.) should not have killed the active stages of the lice. The following experiments were conducted to throw more light on this point.

Exp. 16. Lice not fed for 5 hours were dipped in a solution containing 1 gram of ivory soap to 100 c.c. of water colored blue with trypan blue. Temperature 108°–115° F. (42°–46° C.). Lice removed in 15 minutes and examined by mounting

[18] Combating Lousiness among Soldiers and Civilians.

[19] Physical Properties Governing the Efficacy of Contact Insecticides. *Journ. of Agri. Research* 13: 523-38. 1918.

in alcohol on a glass slide, but no trace of the colored soap solution could be found in the tracheae.

Exp. 17. Same as Exp. 16, but soap solution 1-250 c.c. results negative.
Exp. 18. " " " " " " " 1-500 c.c. " "
Exp. 19. " " " " " " " 1-750 c.c. " "
Exp. 20. " " " " " " " 1-1000 c.c. " "

Exp. 21. Same as Exp. 18, but soap solution at a temperature of 122°–132° F. (50°–56° C.). Lice were killed by the treatment but no trace of the solution could be found in the tracheae.

Exp. 22. Lice placed in soap solution 1-500 at room temperature at 8:13 a.m. and removed at 3:30 p.m. No trace of soap solution in tracheae of specimens examined. Lice divided into two lots; one rinsed in water; the other not rinsed. Both sets revived within an hour.

Since it appeared impossible for the ivory soap solution to enter the tracheae, a solution of Castile soap with much lower cohesion was used but similar negative results were obtained. Soap solutions having failed to enter the tracheae, the question arose as to whether fat solvents or oils could penetrate.

Exp. 23. Lice dipped in xylene stained with Sudan III were examined at the end of 5 minutes but no trace of the stain could be found in the tracheae.

Exp. 24. Lice dipped in ether stained with Sudan II. One specimen examined after 2 minutes but no stain was detected. Stained ether was found in few tracheae of a louse which had been dipped in the ether for 5 minutes, but none was found in a specimen removed after 8 minutes.

Exp. 25. Twelve lice dipped in ether colored with Sudan III, for 10 minutes. Examination showed 7 with no ether in the tracheae and 5 which had ether in several tracheae but none with ether in all the tracheae.

Exp. 26. Four lice dipped in a light lubricating oil stained with Sudan III. Removed after 15 minutes, but no stain could be detected in the tracheae.

Most of the lice in these experiments were dead when removed from the liquid having been killed by the chemical passing directly through the body-wall, since no stain could be detected in the alimentary canal or in the tracheal system. Landois[20] has figured the closing apparatus of the pubic louse, which is similar to that of the clothes louse, and from the above experiments, the conclusion is reached that the louse is able to close this apparatus very quickly, but occasionally, as in the case of ether, a few tracheae are not closed quickly enough to keep out the chemical. A few experiments showed that the tracheae of the dog flea (*Pulex serraticeps*) were filled with stained ether after 1 minute immersion, but that the hog louse (*Haematopinus suis*) and the dog louse (*Haematopinus piliferus*) were somewhat resistant to its penetration, but not nearly so successful as the clothes louse. It is hoped to investigate this interesting observation more fully at some later date.

[20] Untersuchungen über die auf dem Menschen schmarotzenden Pediculinen. *Zeitschr. für wiss. Zool.* 15:494-503. 1865.

Two possible methods of killing the active stages are suggested by these results: first the addition to the washing suds of a chemical capable of penetrating the chitin of the body-wall during the period of washing, and toxic enough to produce its death, and second, the elevation of the temperature of the washing suds sufficiently high to destroy the lice. In general, a chemical capable of penetrating the body-wall during the period of washing would have to be rather volatile and hence not suitable for the work. Judging from published accounts, soaking garments in a bath containing cresol or lysol is practiced to a large extent in Europe.

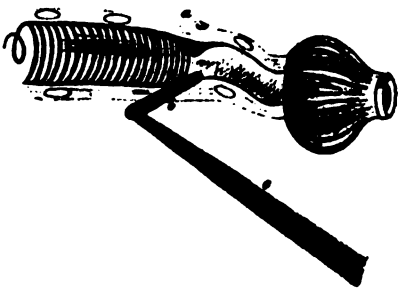


Figure 1
Sketch showing the closing apparatus in the trachea of the pubic louse (after Landois)

The garments, however, are not rinsed following their dip. Peacock[21] found a 1½ per cent cold cresol solution to be capable of destroying the lice and nits soaked in it for one hour. Nuttall[22] found a 5 per cent cresol and soap solution to kill lice and nits in 30 minutes, while a 2 per cent lysol solution at 76° F. (24° C.) killed the eggs after 5 minutes exposure. Bacot and Lloyd[23] consider that "the evidence as a whole seems to establish the fact that steeping for twenty minutes in a 2 per cent solution, either lysol or the cresol soap, is quite effective provided the temperature is not below 50° F." The following experiments were conducted to determine the efficacy of cresol either as a dip preceding washing, or when used in the wash suds.

Exp. 27. Dipped 12 recently fed lice in suds with 1 per cent tricresol added. Temperature 75° F. (24° C.). Transferred after 5 minutes to suds at 110°–114° F. (43°–45° C.) for 15 minutes rinsing in water at 112° F. (44° C.) for 3 minutes. Dried on filter paper when 10 lice revived.

Exp. 28. Same as Exp. 27 but cresol suds at temperature of 110°–114° F. (43–45°C.). 9 lice revived out of 16 used in the experiment.

[21] The Louse Problem at the Western Front. *Brit. Med. Journ.* 2:745-49; 784-88. 1916.

[22] Combating Lousiness among Soldiers and Civilians.

[23] Destruction of Nits of the Clothes Louse by Solutions of Cresol-Soap Emulsion and Lysol. *Brit. Med. Journ.* 1:479-80. 1918.

Exp. 29. Dipped recently fed lice in 1 per cent tricresol in ivory soap suds at 110°–114° F. (43°–45° C.) for 15 minutes, rinsing in water at 112° F. (44° C.) for 3 minutes. Dried, when 1 revived out of 17 lice.

Exp. 30. Dipped in 2 per cent tricresol in suds at 110°–114° F. (43°–45° C.) for 5 minutes. Placed in regular suds at 110°–114° F. (43°–45° C.) for 15 minutes rinsing in water at 112° F. (44° C.). Dried, no lice revived.

Exp. 31. Same as Exp. 30 but with 3 per cent tricresol. All lice killed by the treatment.

From these results, it is apparent that 2 per cent crude tricresol may be added to the washing suds or used as a dip preceding washing and prove effective in the destruction of the lice in the active stages. Altho the pieces of cloth were rinsed after treatment, an odor of cresol persisted, apparently being rather difficult to remove.

Bacot and Lloyd[24] point out that cresol emulsions are liable to decrease in insecticidal value in the presence of organic impurities. To what extent this action takes place is not known and it may vary greatly. Such being the case, and in view of the increased cost of using a chemical to destroy the lice, further experiments were made to determine to what extent heat might be used. A summary of these experiments follows. (Table IV.)

TABLE IV

SUMMARY OF 30-MINUTE TREATMENTS

			Dead	Revived
108°	–110°	avr. 108.8° F.(42.6° C.)	1	7
110°	–113°	avr. 110.7° F.(43.7° C.)	3	7
110°	–115°	avr. 111.6° F.(44.2° C.)	1	16
109°	–115°	avr. 112.4° F.(44.6° C.)	15	1
110°	–115°	avr. 113° F.(45° C.)	18	0
112°	–114°	avr. 113° F.(45° C.)	15	0

SUMMARY OF 22-MINUTE TREATMENTS

110°	–116°	avr. 112.8° F.(44.8° C.)	10	0
113°	–115°	avr. 114.2° F.(45.6° C.)	10	0
114°	–117°	avr. 115.2° F.(46.2° C.)	8	0

SUMMARY OF 15-MINUTE TREATMENTS

111°	–115°	avr. 112.3° F.(44.6° C.)	6	8
111°	–115°	avr. 113° F.(45° C.)	11	0
111°	–115°	avr. 113.3° F.(45° C.)	9	9
112°	–116°	avr. 114° F.(45.5° C.)	10	2
112.5°	–116°	avr. 114.2° F.(45.6° C.)	18	0
113.5°	–117.5°	avr. 114.9° F.(46° C.)	8	0
115.5°	–117.5°	avr. 116.5° F.(46.9° C.)	6	0

These experiments show the lethal temperature for lice is about 113° F. (45° C.) for 22- to 30-minute washings and a slightly higher temperature, 114.5° F. (45.8° C.) proved effective in 15 minutes' time. When woolen garments are quite soiled, the usual practice in laundries is to wash them at the higher temperature of 120°–125° F. (48°–52° C.), care being taken throughout the process to keep the temperature constant which is the important point in washing woolens to prevent shrinkage. These temperatures may be easily maintained in the washing-machine.

[24] Destruction of Nits of the Clothes Louse by Solutions of Cresol-Soap Emulsion and Lysol.

Considering the data presented, the following procedure is recommended for the laundering of woolen goods to destroy both lice and eggs. Infested garments may be washed at a temperature of 120° F. (49° C.), not to fall below 115° F. (46° C.) during the washing period of 15 minutes, this treatment destroying the active stages without the use of any special chemicals. Garments are then treated in the regular manner until perfectly dry, when they should be placed in the hot air tumbler at a temperature of 150°–170° F. (66°–77° C.) for 10 to 15 minutes. This destroys the eggs. By this method, it will be possible to launder woolens without shrinkage, and to destroy the lice and eggs without the use of a special chemical.[25]

These experiments have been corroborated in general by the experiments conducted in the regular army laundering units by Pierce, Moscowitz, and Hutchinson.[26] In their experiments the woolens were washed at a slightly higher temperature, 131° F., and dried in a hot air tumbler without shrinkage resulting.

Effect of heat on woolens.—Pierce and Moscowitz[26] found that shrinkage of woolens took place when heated dry in the tumbler, but did not when the woolens were dried in the tumbler. Woolman and McGowan[27] state that "certain influences increase the felting action, e.g., expansion due to heat, followed by sudden contraction from cold—changing from hot to cold water, or hanging the warm, wet fabric outdoors on a cold day." Fulton and Staniford[28] have shown that in the steam sterilization of woolen blankets, sudden opening of the sterilizer will cause shrinkage, while if only partly opened, allowing a gradual cooling, shrinkage does not result. It would appear, therefore, that if the dry woolens were heated in the hot air tumbler, avoiding too sudden changes in temperature, shrinkage would not result.

Matthews[29] states that in heating wool with water under pressure, the fibre is disorganized, due to the hydrolysis of the wool protein. It is to be expected that steam sterilization would produce such results and that repeated sterilizations would materially reduce the strength of the fabric.

[25] Pierce, Hutchison, and Moscowitz in an article appearing in the *National Laundry Journal* 81: no. 1, January 1919, state that I recommend washing woolens at a temperature of 123° F., preferably 125° F. to destroy the *eggs* of the lice. In the report to which they refer the following statement occurs: "Infested garments to be washed at a temperature of 120° F. not to fall below 115° F. during the washing period of fifteen minutes, this treatment to destroy the active stages without the use of any special chemicals. Garments are then treated in the regular manner until perfectly dry when they should be placed in the tumbler for a period of ten to fifteen minutes resulting in the destruction of the eggs."

W. M.

[26] MS reports to the Surgeon-General's office. August and September, 1918.

[27] Flowers of Sulphur and Lice. *Brit. Med. Journ.* 1:395. 1915.

[28] The Sterilization of Woolen Blankets and Uniforms. *Journ. Amer. Med. Assn.* 71: 823-24. 1918.

[29] The Textile Fibers, Their Physical, Microscopical and Chemical Properties. New York: John Wiley & Sons. 1913.

Presence of an alkali greatly increases the hydrolysis of the wool; hence drying garments in a hot air tumbler, if any alkali were present from the wash water, should produce similar results. The whole question of the effect of dry heat and of steam upon woolens is in need of further investigations before being adopted upon a larger scale.

FUMIGATION

The use of steam or hot air for the sterilization of the garments is superior to the use of a chemical for fumigation purposes, but in many cases, owing to the lack of proper facilities or fuel for carrying out such sterilization, a method of thoroly fumigating garments is necessary. To meet this need, carbon bisulphide,[30] carbon tetrachloride,[31] naphthalene,[32] creolin,[33] sulphur dioxide,[34] hydrocyanic acid,[35] and other chemicals have been considered. The small amount of vapor of the less volatile of these chemicals present in a saturated atmosphere at room temperature makes necessary a considerable degree of heat, or an exposure for a long period of time, to produce the desired results. The more volatile chemicals such as carbon bisulphide or carbon tetrachloride have so low a toxicity that unless large quantities of the chemical are used or the temperature is raised to the boiling point of the chemical, the insects are only stupified and soon revive. The slow penetration of hydrocyanic acid together with the difficulties of generating the gas restricts its use. Similar objections, to which may be added a relatively low toxicity, may be raised to sulphur dioxide.

In a study of the toxicity of a large number of chemicals[36] it was found that chlorpicrin, or nitrochloroform ($CCl_3\ NO_2$), altho quite volatile, possesses a very high toxicity. This high toxicity is due, in a large measure, to the ability of the chitin to absorb from the air even minute quantities of the chemical and to permit it to pass through into the insect's body.[37] In studies dealing with the fumigation of grain and flour, chlorpicrin showed

[30] Beitrage zur Bekämpfung der Kleiderläuse in Kleidern. *Centralbl. f. Bakt. u. Parasitenk.* 1 Abt. Orig. vol. 77:320-38. 1916.

[31] Entläusung mit Tetrachlorkohlenstoffgas. *Münchener med. Wochenschr.* 65:235-37. 1918.

[32] Nuovo metodo di sterilizzazione entom-parassitario. *Ann. d'Igiene.* 26:493-508. 1916. Abstract. *Review of Appl. Entom.* (series B) 4:177-78.

[33] I pidocchi ed i mezzi per distruggerli. *Ann. d'Igiene.* 26:92-108. 1916. Abstract, *Review of Appl. Entom.* (series B) 4:83. Muto, *op. cit.*

[34] Friedmann, *op. cit.*

[35] Insecticidal Fumigation in Ships with Special Reference to the Use of Hydrocyanic Acid and to the Prevention of Ship-Borne Yellow Fever. *Med Journ. of Australia* Nov. 4, 1916.
Entläusung durch Zyanwasserstoff. *Deutsch. med. Wochenschr.* 43:303-4. 1917.

[36] Volatility of Organic Compounds as an Index of the Toxicity of Their Vapors to Insects. *Journ. of Agric. Research* 10:365-71. 1917.

[37] Physical Properties Governing the Efficacy of Contact Insecticides.

great penetration.[88] Experiments were therefore conducted to determine its value in the fumigation of clothing to destroy lice and their eggs. Inasmuch as under field conditions only the simplest apparatus is available for the work, the fumigations were carried out in an ordinary galvanized iron ash can, without special efforts to make it air tight. Chlorpicrin of the desired quantity was poured upon the garments, while they were being packed in the can, thus insuring a more rapid evaporation and penetration. The results of these experiments (Table V) show that to evaporate the chlorpicrin rapidly in order that it may penetrate all parts of the clothing and destroy the eggs of the lice within 30 minutes, a small amount of heat is necessary. Three one-liter flasks filled with water heated to 80°–85° C. were found to answer the purpose. In practice the box might be heated to 30°–35° C. or hot stones might be used in the same manner as the flasks. Where no heat was available, a longer exposure is necessary. The active stages are more easily destroyed than eggs; hence in only two experiments were active stages used. They were placed in vials closed with gauze and the vials placed in pockets of the trousers in folds of the cloth, and in one case wrapped in 3 thicknesses of heavy underwear and placed in a leather ax case which was then strapped shut. The lice were used in experiments F and C and were in all cases killed.

Inasmuch as chlorpicrin is used in gas warfare, a supply should be available on the fighting front. Owing to its poisonous nature, and its irritating effect on the eyes, nose, and throat, it would be necessary for the operator to use a gas mask. Airing the clothing in the open for 3 to 5 minutes is sufficient to remove the chlorpicrin, after which the clothing can be worn.

No bleaching or fading of colored fabrics was observed in a number of tests made with fabrics of delicate coloring, providing the chlorpicrin contained no impurities of chlorine or nitrogen peroxide.[89] No injurious effect on leather was observed, but rubber is injured somewhat, altho not as much as might be expected.

The use of chlorpicrin is recommended as a means of delousing garments under conditions prohibiting the use of hot air or steam, since no particular apparatus is needed for the work. Chlorpicrin is superior to other chemicals recommended for fumigation since, on account of its extreme toxicity, high volatility, and ability to penetrate through masses of clothing, a high temperature is not necessary to insure the destruction of both eggs and active stages of the lice in a short period of time.

[88] Fumigation with Chlorpicrin. *Journ. of Econ. Ento.* 11:357-62. 1918.

[89] *Ibid.*

TABLE V

FUMIGATIONS WITH CHLORPICRIN

Treatment	Location of eggs in clothing	Age in days of eggs at time of fumigation	No. of eggs	Per cent hatched
A-6 c.c. of chlorpicrin in fumigation box of 2.5 cu. ft. for 20 minutes	Under seam of trouser leg	13	6	0
	Watch pocket of trousers	12	6	0
	In a fold of trousers	11	6	33.3
	Folded in bottom of cotton shirt	10	6	16.6
	Under collar of cotton shirt	9	7	100
	Pinned to front of flannel shirt	8	11	100
	Under neck of shirt	7	7	55.7
	Wrapped in piece of underwear in pocket of coat	6	8	75
	In pocket of heavy overcoat	5	11	27.2
	In pocket of heavy overcoat	4	2	100
	Wrapped in piece of underwear placed in leather ax case	3	7	28.6
	Rolled in sleeve of undershirt	2	7	57.1
	In cuff of flannel sleeve then rolled up	1	6	16.6
	In pocket of cotton shirt	½	8	37.5
B-10 c.c. of chlorpicrin to 2.5 cu. ft. for 30 minutes	Wrapped in underwear and placed in leather ax case	13	6	33.3
	Pocket of trousers	12	6	0
	Underwear pocket folded 3 times	11	5	0
	Bottom seam of cotton trousers rolled over 3 times	10	5	0
	Collar of cotton coat	9	7	42.8
	Pinned to front of undershirt	8	12	33.3
	Seam of khaki trousers	6	7	37.5
	Underneath collar of flannel shirt	6	7	42.8
	Cuff of flannel shirt sleeve rolled up	5	7	28.5
	Pocket of coat	4	6	0
	Pocket of overalls	3	7	55.7
	Pocket of heavy overcoat	2	8	0
	Sleeve of undershirt	1	7	0
	Under collar of cotton overalls	½	6	0
C-10 c.c. of chlorpicrin to 2.5 cu. ft. for 10 minutes	Wrapped in underwear placed in pocket of overalls	13	6	0
	Seam at bottom of overall. Leg rolled up	12	6	0
	Waist band of overalls	11	5	0
	Under collar of flannel shirt	10	5	0
	Rolled in sleeve of shirt	9	7	55.7
	In fold of khaki trousers	8	10	30

TABLE V—*Continued*

FUMIGATIONS WITH CHLORPICRIN

TREATMENT	LOCATION OF EGGS IN CLOTHING	AGE IN DAYS OF EGGS AT TIME OF FUMIGATION	NO. OF EGGS	PER CENT HATCHED
	Pinned to front of flannel shirt	7	10	80
	Wrapped in underwear placed in pocket of shirt	5	6	16.6
	Bottom seam of khaki trousers	6	9	11.1
	Pinned to bottom of coat	4	7	0
	Placed in overall pocket	3	9	0
	Placed in leather ax case	2	8	0
	Placed in pocket of cotton shirt	1	6	33.3
	Pinned to back of cotton shirt	½	6	0
D-control for A, B, and C		13	5	20
		12	7	14.3
		10	1	100
		9	50	84
		8	36	75
		7	15	40
		6	4	0
		5	5	40
		4	8	0
		3	6	16.6
		2	6	0
		1	7	0
		½	8	0
E-10 c.c. of chlorpicrin to 2.5 cu. ft. for 15 minutes. Heated by placing in box 3 1-liter flasks filled with water at 80° C.	Under collar of coat	12	7	0
	In leather ax case	11	5	0
	Wrapped in cloth in pocket of khaki trousers	10	6	0
	Under collar of shirt	9	6	0
	Under front seam of trousers	8	5	0
	In fold of trouser leg	7	5	0
	Wrapped in a piece of underwear placed in shirt pocket	6	4	0
	Placed in pocket of heavy overcoat	5	3	0
	Wrapped in an undershirt	4	6	0
	Pinned to gray flannel shirt	3	4	0
	Attached to sleeve of gray shirt. Rolled up 6 folds	2	6	16.6
	Pocket of gray coat	1	6	0

TABLE V—*Continued*

FUMIGATIONS WITH CHLORPICRIN

Treatment	Location of eggs in clothing	Age in days of eggs at time of fumigation	No. of eggs	Per cent hatched
	Pinned in fold of khaki trousers	½	6	0
F-10 c.c. of chlorpicrin to 2.5 cu. ft. for 30 minutes	Pocket of gray coat	13	6	0
	Wrapped in cloth in pocket of khaki trousers	12	6	0
Heated by 3 1-liter flasks filled with water at 82° C.	Under collar of gray shirt	10	6	0
	In pocket of heavy overcoat	9	6	0
	Sleeve of flannel shirt rolled up 6 folds	8	4	0
	In fold of undershirt	5	6	0
	Under collar of gray flannel shirt	3	6	0
	Rolled up in leg of cotton trousers	2	4	0
	Attached to seam of cotton trousers	1	6	0
	Pinned to gray flannel shirt	½	6	0
G-10 c.c. of chlorpicrin to 2.5 cu. ft. for 15 minutes. Heated with 3 1-liter flasks filled with water at 80° C.	Pocket of khaki overalls	13	8	0
	Pocket of gray coat	12	7	0
	Wrapped in cheesecloth pinned under arm of flannel shirt	11	6	0
	Pinned to front of undershirt	10	2	0
	Pinned to shoulder seam of flannel shirt	9	5	20
	Under collar of cotton shirt	5	6	0
	In pocket of heavy cotton shirt	3	6	0
	Under leg seam of khaki overalls	1	6	0
	In watch pocket of cotton trousers	½	6	0
H-control for E, F, and G		13	4	0
		12	5	40
		11	8	0
		10	6	16.6
		9	6	0
		8	7	0
		7	5	0
		6	3	0
		5	6	0
		4	6	0
		3	6	50

TABLE V—*Continued*

FUMIGATIONS WITH CHLORPICRIN

Treatment	Location of eggs in clothing	Age in days of eggs at time of fumigation	No. of eggs	Per cent hatched
H-control for E, F, and G		2	6	0
		1	6	66.7
		½	6	0
I-10 c.c. of chlorpicrin to 2.5 cu. ft. for 30 minutes Heated by 3 1-liter flasks of water at 80° C.	Rolled up in sleeve of woolen jacket 6 folds	14	7	0
	Under arm seam of woolen jacket	13	10	0
	Under fold of cotton shirt	12	10	0
	Under collar of heavy cotton shirt	11	9	0
	In watch pocket of khaki overalls	10	10	0
	In thick fold of leg of khaki overalls	9	9	0
	In pocket of heavy cotton trousers	8	10	0
	Under leg seam of cotton trousers	7	10	0
	Pinned to front of undershirt	6	10	0
	Inside sleeve of undershirt	5	10	0
	Under arm seam of cotton coat	4	10	0
	Under sleeve seam of cotton coat	3	10	0
	Pocket of cotton coat	2	10	0
	Under collar of gray flannel shirt	1	10	0
	Folded in cuff of gray flannel shirt	½	10	0
J-control for I		14	6	0
		13	10	10
		12	10	10
		11	10	50
		10	10	10
		9	10	10
		8	10	10
		7	10	60
		6	10	80
		5	10	20
		4	10	30
		3	10	30
		2	10	30
		1	10	10
		½	10	20

TABLE V—*Continued*

FUMIGATIONS WITH CHLORPICRIN

Treatment	Location of eggs in clothing	Age in days of eggs at time of fumigation	No. of eggs	Per cent hatched
K-10 c.c. of chlorpicrin to 2.5 cu. ft. for 20 minutes 3 1-liter flasks of water at 80° C. used to heat fumigation box	Pinned along seam of brown trousers	17	7	0
	In triple fold of brown cotton trousers	14	9	0
	Pinned at waist of brown cotton trousers	13	7	0
	Pinned in double fold of cotton trousers	13	8	0
	Rolled 4 folds in undershirt	12	8	25
	Pinned to edge of undershirt	12	7	14.3
	Pinned to front of undershirt	11	11	18.1
	Folded under collar of undershirt	11	10	0
	Folded under 6 folds of collar of flannel shirt	10	9	33.3
	Pinned to collar of flannel shirt	10	8	25
	Pinned in 5 thicknesses of woolen cloth	9	11	27.2
	Pinned to outside of woolen cloth	9	10	20
	Attached to cuff of cotton coat rolled 16 times	8	10	0
	Attached to cuff of cotton coat rolled 6 times	8	9	0
	Attached to outside of cotton coat	8	10	0
	Attached to cuff of light cotton coat. Rolled 13 times	7	8	0
	Attached to outside of above roll	7	7	0
	Attached to cuff of flannel coat tightly rolled 20 times	6	10	0
	Attached to cuff of flannel coat tightly rolled 8 times	6	10	0
	Attached to outside of flannel coat tightly rolled	6	8	12.5
	Bottom of khaki overalls. Tightly rolled 12 times	5	11	9
	Bottom of khaki overalls. Tightly rolled 6 times	5	10	10
	Outside of khaki overall roll	5	13	7.7
	Inside of cotton pad rolled 3 times	4	11	17.2
	Outside of cotton pad	4	11	0
	Pinned to back of cotton collar	3	3	33.3
	Pocket of cotton coat	2	7	0
	Pocket of khaki overalls	1	12	25
	Pinned to front of cotton shirt	½	9	0

TABLE V—*Continued*

FUMIGATIONS WITH CHLORPICRIN

Treatment	Location of eggs in clothing	Age in days of eggs at time of fumigation	No. of eggs	Per cent hatched
L-control for K		17	7	0
		14	4	50
		13	17	47
		12	15	40
		11	22	27.2
		10	17	17.7
		9	19	16
		8	27	22.2
		7	18	22.2
		6	25	4
		5	36	30.5
		4	21	33.3
		3	2	100
		2	7	57.1
		1	11	27.2
		½	8	50

METHODS OF LOUSE DESTRUCTION BY PEDICULICIDES

Even tho the methods of freeing the soldiers' clothing of lice should be perfect, in practice it is impossible to carry out such measures with more than a limited number of men in one day. Further, it appears to be impossible to segregate the clean men until such time as their comrades have been cleaned. Such being the case, the soldier comes in contact with lousy men and becomes reinfested, not once but possibly many times in the period between lousings. It is for this reason that the need of a good pediculicide arose, and it is possible that, due to the lack of such a pediculicide, the louse problem reached the magnitude it has in the present war. To supply this need large numbers of chemicals have been experimented with and recommended for use. Hase[40] mentions as many as 181 in his experiments, while Nuttall[41] lists 110 that have been recommended in practice. The motto in the work appears to be "try everything" and this has been done without an effort being made to determine any of the principles which may govern the action of the chemicals. The present investigation was conducted primarily to ascertain first, the principle upon which the insecticide acts, and second, by the application of this principle, to produce better preparations. Many chemicals have been used, not with the idea of their value as pediculicides, but rather to elucidate the action of chemicals used in that manner. Throughout the work certain principles governing the toxicity of volatile organic compounds have been used which were discovered previous to this investigation.[42] These principles may be briefly outlined as follows:

1. The volatility, of which the boiling point is in general an index, influences to a marked extent the toxicity of the vapor of the chemical.
2. The lower the boiling point of a chemical the greater is the quantity of the chemical which may be held by a given quantity of air.
3. Using a saturated atmosphere of the vapor of a chemical, it was found that death was produced most quickly by the chemical with the lowest boiling point (highest volatility), while compounds with very high boiling points required long periods of time to produce death.
4. Using equal quantities of the vapor, death is produced most quickly by the compound with the highest boiling point (lowest volatility).

An example of the manner in which these principles work may make the meaning clearer. A saturated atmosphere of benzene (b.p. 80.36° C.) containing about .184 grams per liter of air will kill house flies in about 13 to 15 minutes at a temperature of 20°–22° C. while a saturated atmosphere of nitrobenzene (b.p. 205° C.), which contains only about .004 grams

[40] Weitere Beobachtungen über die Läuseplage. *Centralbl. f. Bakt. u. Parisitenk.* 1 Abt. Orig. vol. 77: 153-63. 1915.

[41] Combating Lousiness among Soldiers and Civilians.

[42] Volatility of Organic Compounds as an Index of the Toxicity of Their Vapors to Insects. Physical Properties Governing the Efficacy of Contact Insecticides.

per liter, requires 115 minutes. On the other hand, using equal quantities of the vapor it is found that .004 grams of benzene act so slowly that more than 7 hours are required to produce death. This period is so long that death may not be entirely due to the action of the benzene vapor. Naturally, chemical activity has a bearing upon its toxicity, but in general, unless the chemicals have nearly the same volatility, the difference in chemical activity is entirely masked by the changes in toxicity due to changes in volatility.

An examination of the louse problem shows four different methods by which a pediculicide may be applied; first, direct contact of the chemical; second, sachets; third, louse powders; fourth, impregnation of the underwear.

Direct Contact of the Chemical

Many different chemicals have been recommended to be rubbed along the seams of the clothing to destroy lice and their eggs. Some of these compounds are for the purpose of killing by direct contact, while others are thought to act as repellants. Almost any active liquid chemical with a boiling point above 160° C. and below 250° C. will destroy lice and their eggs when brought into direct contact with them; hence no special investigation of this phase of the problem was made. Cresol or lysol are possibly the cheapest of the chemicals which might be used for this purpose. Inasmuch as all the lice and nits would not be reached by this method, and since it would not protect from reinfestation, it can not be recommended as an effective method of louse control.

Concerning the use of repellants, observations with many chemicals throughout the experiments show that those compounds which acted as repellants were actual poisons, present in too small quantities actually to kill the lice, or very slow in action, due to a very low volatility. It appears very doubtful if a compound repellant to lice exists which, under more favorable conditions, would not actually kill them.

Use of Sachets

Primitive man protected himself from different ills and evil influences by wearing a charm suspended from the neck, while modern man continuing the same method, has substituted a bag of asafoetida or camphor for the charm. Such is probably the origin of the sachet method of protecting the soldier from attacks of lice. Naphthalene,[43] camphor,[44] sulphur,[45] paradichlorbenzene,[46] and various other chemicals[47] have been used in sachets

[43] Zur Prophylaxe des Flecktyphus. *Deutsch. med. Wochenschr.* 41:12. 1915.

[44] Mesures prophylactiques contre le typus exanthématique et le typus récurrent. *Paris Med.* 5:206-12. 1915. Abstract, *Review of Appl. Entom.* (series B) 3:232.

[45] Shipley, *op. cit.*

[46] Hase, *op. cit.*

[47] Control of Lice in the Active Army. *Proc. Confer. Bacter. Moscow* pp. 70-71. 1915. Abstract, *Review Appl. Entom.* (series B) 3:122-23.

worn suspended from the neck or from the waist of the soldier. Inasmuch as these chemicals give off a vapor which is toxic to insects, it was thought that this method might be of some value in the destruction of the lice. In the preliminary experiments, muslin bags containing 5 to 10 grams of the chemical to be tested were suspended from the neck while a wide-mouthed vial containing the lice was fastened at the waist line. The opening of the vial was closed by means of a piece of bolting cloth, to prevent the escape of the lice. Naphthalene, paradichlorbenzene, and chloretone were used in these experiments, but the lice were not only active but even laid eggs during the exposure. One experiment in which naphthalene was used, had the bag located not more than 5 or 6 inches from the vial. The subject slept, covered with a heavy woolen blanket in addition to the normal clothing, and after an interval of several hours the lice were found to be dead.

From results of previous experiments with insects, even small quantities of these chemicals having rather high boiling points should prove toxic to the lice. Two explanations are possible to account for their failure; either the diffusion of the vapor was so slow that it failed to reach the lice in sufficient quantity to prove fatal, or the rate at which the chemical escaped from the space between the body and the clothing was so rapid compared with the rate at which it evaporated, that not sufficient vapor was retained under the clothing to bring about the death of the lice. In large glass cylinders where there is no opportunity of escape, the vapor diffuses sufficiently in a few hours to kill lice in all parts of the vessel. It appears, therefore, that the ineffectiveness of these compounds must be due to the rapidity with which their vapors escape from the clothing. The following experiments were conducted to determine the accuracy of this point.

Five-gram lots of the compounds to be tested were weighed out in watch glasses and placed in wide-mouthed jars lying on their sides. The openings of the jars were covered with different types of cotton, wool, and silk underwear, woolen and khaki clothes, and combinations of these to as many as three or four thicknesses. Our control jar was left open, while another was closed with a glass top. From a comparison of the amount of evaporation from these jars, it is possible to arrive at an estimation of the amount of diffusion through the different types of clothing. In the case of the jar closed with a glass top, the air soon became saturated with the vapor after which no further evaporation occurred. This amount was so small in the case of camphor, naphthalene, and paradichlorbenzene, that no difference in weight could be detected in the compound. The loss in weight due to evaporation from the open jar was considered as representing the quantity of vapor, which escaped and was taken as 100 per cent. Upon this basis, it was found that the loss in weight of naphthalene contained in jars closed with different types of clothing varied from 44 per cent to 88 per cent, and paradichlorbenzene from 55 per cent to 62 per cent of

the loss in weight from the open jar. (Table VI.) These experiments were all conducted in a room heated to a temperature of 26°–28° C.

From these results, it is apparent that not more than 15 to 50 per cent of a saturated atmosphere of these chemicals could be retained under the soldiers' uniform. In actual practice, the percentage is much less, due to the escape of the vapor through openings about the neck, arms, etc., the diffusion being increased by movements of the diaphragm.

TABLE VI

EVAPORATION OF VOLATILE COMPOUNDS FROM JARS CLOSED WITH DIFFERENT KINDS OF CLOTH

Naphthalene	Per cent
Check	100
Light cotton gauze underwear	66
Medium cotton and wool underwear	88
Medium cotton underwear	66
Medium silk and cotton underwear	66
Medium silk underwear	88
Heavy cotton fleece-lined underwear	88
Heavy cotton and wool underwear	85
Blue flannel	77
Double blue flannel	44
Muslin underwear, woolen shirt, khaki coat	50

Paradichlorbenzene	Per cent
Check	100
Medium wool and cotton underwear	62
Fleece-lined cotton underwear	55
Light cotton gauze underwear	60

Xylene	Per cent
Check	100
Fleece-lined cotton underwear	46
Light gauze cotton underwear	50
Medium silk underwear	50
Medium wool and cotton underwear	42
Heavy cotton underwear	46
Muslin underwear, woolen shirt, khaki coat	43

Such low percentages of saturation are not sufficiently high in the cases of naphthalene, paradichlorbenzene, camphor, etc., to result in effective control of the lice. Bacot[48] obtained similar results, but considered them to be due to the slow diffusion of the chemicals tested.

Better results might be obtained by selecting such chemicals as have a rate of evaporation high enough to overcome in a large measure the loss due to leakage through the clothing. Similar experiments were therefore conducted with xylene mixed with fuller's earth. The leakage amounted to from 40 per cent to 45 per cent, while 50 per cent of a saturated atmosphere of xylene is sufficient to produce death. Bags of fuller's earth containing xylene, worn about the neck, killed lice contained in a vial suspended at the waist line, but the xylene in contact with the skin burned

[48] The Use of Insecticides against Lice. *Brit. Med. Journ.* 2:447-50. 1916.

and produced blisters. This objection was overcome by preventing the bag from coming in contact with the skin by means of a piece of tin foil or rubber sheeting.

An opportunity of determining the value of this method presented itself when a student was found infested with the pubic louse. He consented to give the sachet method a trial under conditions similar to those encountered in the field. Two bags containing fuller's earth and xylene were attached to a tape tied around the body about 3 inches above the waist line. Within 6 hours all the lice were stupified and fell down his trouser legs, lodging in his underwear below the knees. In this position there was insufficient vapor of xylene to bring about death, and in a few hours the lice revived, attaching themselves to the hairs of his leg in the form of a circle. Other means were then taken to free him of these objectionable insects.

From these experiments it is apparent that sachets of naphthalene, camphor, paradichlorbenzene, or other high boiling point compounds would not be successful in practice, since the leakage through the clothing is too rapid in comparison with their rate of evaporation. Chemicals with lower boiling points, such as xylene, will evaporate rapidly enough to maintain a quantity of vapor under the clothing sufficient to produce the death of the lice. Owing to the fact that the lice are first stupified, and fall into a region where the vapor is absent or not present in sufficient quantity to produce death, it would be necessary to attach one or more sachets on each leg. Considering the large quantity of xylene evaporating each day from one sachet, and adding to this the large number of sachets which would have to be worn to prove effective, it is at once apparent that the expense makes protection by means of sachets impossible.

In order that a chemical with a high boiling point may be used successfully as a pediculicide, its evaporation must be increased by exposing a large surface of the chemical. This may be accomplished in two ways, either in the form of a powder dusted through the clothing or by the direct impregnation of the underwear. Either method further increases the action of the chemical by bringing it into direct contact with the louse.

Louse Powders

Powders have been used extensively in the control of parasitic insects on domesticated animals, and it is natural that similar powders should be recommended for the destruction of clothes lice. Pyrethreum powder has been extensively used as a louse powder, or as the chief ingredient of the louse powders. Pyrethreum, altho it will destroy lice in contact with it for a long period, usually first stupified the lice, causing them to fall out of the active zone of the powder. Naphthalene has been used as a louse powder with more or less success, but the most successful powder has

been the N. C. I. powder[49] made of naphthalene, 96 per cent, creosote, 2 per cent, iodoform 2 per cent.

The N. C. I. powder.—Altho N. C. I. has proved most successful, several objections have been offered to this preparation; first, that it is moist, and hence difficult to dust through the clothing, and second, it is inclined to burn the skin, particularly in the fork of the legs. Preliminary experiments agreed with the results of Kinlock[50] that an atmosphere saturated with the vapor of the combined powder was more toxic than the vapor of any one of its constituents. The problem, therefore, was to determine the cause of this increased toxicity. It would appear that the creosote being more volatile than either naphthalene or iodoform would evaporate, leaving a powder composed of naphthalene and iodoform only. Observations have shown that when N. C. I. is exposed to the air for several days it becomes dry and is then of no more value as a louse powder than naphthalene itself. Naphthalene and iodoform being somewhat soluble in creosote, a saturated solution of both these chemicals was prepared. This solution proved as toxic as the N. C. I. powder. Inasmuch as the two grams of creosote present in 100 grams of N. C. I. would dissolve only about one third of a gram of naphthalene and about one twelfth of a gram of iodoform, there does not appear to be any reason why such large quantities of these chemicals should be used in the powder. After experiments with Lloyd's alkaloid reagent, fuller's earth, and a few other similar inert ingredients, talc was selected as a basis for the powder. Using talc, a larger quantity of creosote could be used and the finished product still remain dry in comparison with the moist N. C. I. The powder made of twenty grams of talc, one-half gram of naphthalene, one-half gram of iodoform and 1 c.c. of creosote was found to be just as effective as the N. C. I., with the added advantage of being drier and much cheaper. (Table VIII.) Experiments showed that the creosote alone was not as effective as when either naphthalene or iodoform was added, but creosote naphthalene, or creosote iodoform, appeared to be slightly better than a combination of all three chemicals.

TABLE VII

VOLATILITY OF CERTAIN CHEMICALS USED IN LOUSE POWDERS

Compound	Grams per sq. cm. ½ hour
Creosote	.001312
Methyl salicylate	.002424
Naphthalene	.0008609
Iodoform	.0001716
Naphthalene in creosote 8 per cent solution	.001622
Naphthalene creosote 50–50	.001928
Iodoform in creosote saturated solution	.001202
Iodoform and naphthalene in creosote saturated solution	.001806
Sulphur in creosote saturated solution	.001323
Naphthalene in methyl salicylate	.003451

[49] Peacock, *op. cit.*

[50] An Investigation of the Best Methods of Destroying Lice and Other Body Vermin. *Brit. Med. Journ.* 1:789-93. 1916.

Principles of louse powders.—The value of the N. C. I. or a similar powder appears to be due to the less volatile and more toxic naphthalene and iodoform evaporating with the creosote, just as in fractional distillation the lower fraction of a liquid carries over small quantities of the higher boiling liquid. At the time that the powders listed in Table VIII were prepared and tested, this point could not be definitely determined, but after the apparatus for studying volatility, described later in this paper, was available, data were obtained. (Table VII.) From these results it is seen that the addition of naphthalene to creosote or methyl salicylate increases the loss in weight per half-hour. The loss is greater with methyl salicylate, possibly due to the greater solubility of naphthalene in it. The addition of iodoform slightly reduces the loss in weight while sulphur does not appear to affect it. By the evaporation of saturated solutions of naphthalene or iodoform in creosote to dryness at room temperature, it was found that the creosote carries the naphthalene or iodoform with it. When naphthalene and iodoform were both present to saturation in the creosote, crystals were found in the dish, as it approached dryness, showing that the creosote could not carry both as well as it could either one. From a mixture of .09 grams of sulphur with 7.7 grams of creosote, after evaporation, .0856 grams of sulphur were recovered. Considering the possibilities of the loss of particles of sulphur during its recovery, it is apparent that in evaporating, the creosote carries very little, if any, sulphur with it. A good louse powder would, from these studies, contain a liquid of about the volatility of creosote, in which was dissolved a more toxic and less volatile liquid or solid, to be carried to the insect by the vapor of the more volatile portion. These chemicals forming the active principle of the louse powder can then be mixed with an inert carrier such as talc, in order that the finished powder may be dry and easy to dust through the clothing.

Experiments with different powders.—Using this principle, it was found easy to make any number of powders equal or surpassing N. C. I. in toxicity. Pieces of underwear were dusted with the powder and laid over a small square of cloth to which the lice were attached. At the end of the period of time determined for the experiment, the underwear was removed and all particles of powder adhering to the lice removed as far as it was possible. The lice were then placed in a clean vial, and left for 12 to 24 hours in the incubator to determine the percentage actually killed. This precaution was necessary as lice are often stupified, possibly due to the closure of their spiracles in the presence of a toxic vapor, just as when they are dipped in soap solutions. An examination of the results show that methyl salicylate is not as good as creosote, possibly due to its greater volatility. Crude phenol or crude cresol would serve better as substitutes. Many of the toxic chemicals used would be too poisonous or too expensive for use on the body, but are listed to show the correctness of the principle

TABLE VIII

EXPERIMENTS WITH LOUSE POWDERS

Composition of powders	Per cent killed in minutes			
	5 min.	10 min.	20 min.	30 min.
N.C.I. (naphthalene 96 per cent, creosote 2 per cent, iodoform 2 per cent)	...	...	66	100
Talc 20 grams, naphthalene ½ gram, creosote 1 c.c. iodoform ½ gram	...	...	66	100
" 20 " creosote 1 c.c.	...	...	0	100
" 20 " creosote 1 c.c., naphthalene ½ gram	...	66	100	100
" 20 " creosote 1 c.c., iodoform ½ gram	...	0	100	100
" 20 " creosote ½ c.c., oil of sassafras ½ c.c.	...	...	...	0
" 20 " creosote ½ c.c., amyl alcohol ½ c.c.	...	...	0	100
" 20 " creosote ½ c.c., methyl salicylate ½ c.c.	...	...	0	100
" 20 " creosote ½ c.c., carbolineum ½ c.c.	...	...	0	0
" 20 " creosote ½ c.c., crude phenol ½ c.c.	66	100	100	100
" 20 " creosote 1 c.c., chloretone ½ gram	..	33	100	...
" 20 " methyl salicylate 1 c.c., chloretone ½ gram	...	...	0	...
" 20 " creosote 1 c.c., alpha-naphthylamine ½ gram	...	...	66	...
" 20 " methyl salicylate 1 c.c., alpha-naphthylamine ½ gram	...	...	33	...
" 20 " creosote 1 c.c., paranitrophenol ½ gram	...	33	100	...
" 20 " methyl salicylate 1 c.c., paranitrophenol ½ gram	...	...	66	...
" 20 " methyl salicylate 1 c.c., iodoform ½ gram	...	...	0	...
" 20 " methyl salicylate 1 c.c., naphthalene ½ gram	...	...	0	...
" 20 " methyl salicylate 1 c.c., quinone ½ gram	...	100	100	...
" 20 " methyl salicylate 1 c.c., paranitrobenzylchloride ½ gram	...	...	33	...
" 20 " creosote 1 c.c., ortho- and parachlornitro-benzene ½ gram	...	66	100	...
" 20 " creosote 1 c.c., picric acid ½ gram	...	...	0	...
" 20 " creosote 1 c.c., alphanaphthol ½ gram	...	66	100	...
" 20 " creosote 1 c.c., betanaphthol ½ gram	...	66	100	...
" 20 " creosote 1 c.c., paradibrombenzene ½ gram	66	100	100	...
" 20 " creosote 1 c.c., menthol ½ gram	...	...	66	...
" 20 " creosote 1 c.c., monochloracetic acid ½ gram	100	100	100	...
" 20 " creosote 1 c.c., chloranil ½ gram	...	...	0	...
" 20 " creosote 1 c.c., sulphur ½ gram	100	100	100	...
" 20 " creosote 1 c.c., cumarin ½ gram	...	66	100	...
" 20 " creosote 1 c.c., camphor ½ gram	0	100	100	...
" 20 " creosote 1 c.c., isoborneol ½ gram	66	100	100	...
" 20 " creosote 1 c.c., monobromated camphor ½ gram	66	100	100	...
" 20 " crude phenol 1 c.c., naphthalene ½ gram	...	0	...	...
" 20 " crude phenol ½ c.c., creosote ½ c.c., naphthalene ½ gram	...	66	...	...
" 20 " creosote 1 c.c., naphthalene and sulphur to saturation	33	100	...	...
" 20 " creosote 1 c.c., sulphur to saturation	66	100	...	...

upon which the powders were prepared. The chemicals which in the later studies proved best for the impregnation of the underwear could also be used in the manufacture of effective louse powders.

The results obtained with creosote and sulphur were surprising, since sulphur is not carried by the vapor of creosote. Considered from the standpoint of cheapness, results, and effect on the skin, talc 20 grams, creosote 1 c.c. and sulphur ½ gram formed the best louse powder. A number of experiments were tried with this powder, and, altho in some cases the lice when removed from the powder at the end of five minutes showed signs of life, in all cases they died within the next few hours. The experiments with creosote saturated with sulphur demonstrated that an excess of sulphur was necessary to give the best results. Sulphur alone dusted on underwear and covered over the lice for 5-, 10-, or 20-minute periods, failed in all cases to kill the lice, or even to stupify them. Sulphur has often been advised for use in destroying lice, but altho some results are favorable, others are just as unfavorable. It may be that when sulphur is brought into contact with the lice under the proper conditions it proves destructive, while if these conditions are not attained, unfavorable results are obtained. The creosote present in the powders may, by bringing the sulphur into close contact with the louse, produce conditions favorable to the effective action of the sulphur.

The sodium or calcium salt of cresol or a halogenated cresol, described in the section dealing with the impregnation of the underwear, might be used successfully as a louse powder. Particles of these chemicals remaining in the underwear would be gradually decomposed by the action of carbon dioxide and moisture given off by the body, forming the original cresol. Such a powder would be effective for a longer period than those previously mentioned.

The use of powders.—Two points may be mentioned concerning the use of powders to destroy lice. The soldier, in general, objects to their use since effective powders are inclined to produce irritation, particularly when the soldier is perspired, while powders which do not burn are of no value. The second point is the enormous quantity of powder necessary to treat effectively the great numbers of men at the front. Using two ounces of powder for one application, the quantity which would be necessary for good results, would mean 1,250 pounds to each ten thousand men. The action of the powder is such that few, if any, eggs of the lice would be destroyed; hence it would be necessary to repeat the treatment about every two days. The quantity of powder demanded for an army would be enormous, and when one considers that about 90 per cent of the powder is inert material, its use can not be recommended other than as a supplementary control measure for use under exceptional conditions.

Impregnation of the Underwear

Lobaczewski[51] used Ol. bettulae 30 per cent in 96 per cent alcohol to impregnate underwear, claiming that the effect was lasting. Bacot[52] used a mixture of equal quantities of crude carbolic acid and soft soap diluted with water to make a 5 to 10 per cent carbolic acid solution. Shirts impregnated with this chemical were effective for about a week. Gunn[53] used 10 per cent of naphthalene and 10 per cent sulphur dissolved in benzene or gasoline to impregnate cheese cloth garments, which were worn at the front and reported to be very effective. No definite experiments are given, and since naphthalene will evaporate from such a suit within 24 to 48 hours, and Bacot[54] has shown sulphur impregnations to be ineffective, it is doubtful if such suits are of any insecticidal value. Cytisine was experimented with by Bacot[55] but was discarded due to its high toxicity, being an alkaloid similar in physiological effects to nicotine. Nuttall[56] mentions experiments by Peacock with calcium monochlorcresol and copper monochlorcresol as being effective, but of no use when men are heavily infested.

Since impregnation appears to be the most efficient method of applying the insecticide, but a method which has not been extensively investigated, a long series of experiments was conducted to determine its possibilities.

The use of oils.—Hase[57] has shown that when the underwear is worn until it becomes dirty and greasy that few or no lice are found in it. In northern Minnesota some of the lumbermen also recognize this method of ridding themselves of lice. Whether this practice is of value due to the grease or oil present in the underwear proving objectionable to the lice or to the higher temperature under such underwear is not known, but it is interesting to know that in Africa many tribes of natives rub their bodies with oil or grease and such natives are usually comparatively free of lice. Due to these suggestive observations, in the first experiments, oils were used to impregnate underwear. The essential oils were not used since they depend for their effectiveness largely upon volatile fractions which soon disappear. Slightly volatile or non-volatile mineral, vegetable, and animal oils were used to saturate pieces of woolen underwear which were then cut into pieces about 1 cm. square and placed in small vials. Lice were then introduced and the vial placed in the incubator. The lice were fed twice a day, and as it was noted that in many cases the lice were inclined

[51] Zur Frage der "Entläusung." *Wien. klin. Wochenschr.* 28:373-74. 1915.

[52] The Use of Insecticides against Lice.

[53] A Note on the Prevention of Pediculosis. *Brit. Med. Journ.* 1:579-80. 1917.

[54] The Use of Insecticides against Lice.

[55] *Ibid.*

[56] Combating Lousiness among Soldiers and Civilians.

[57] Hase, *op. cit.*

TABLE IX

IMPREGNATION WITH OILS

Oils used in the experiments	No. of c.c. used to 1 sq. in.	Viscosity water = 1	No. of lice used in experiment	Percentage dead at different periods of time (hours) 12	24	36	48	60	72	84	96	108	120	No. of eggs laid	Per cent of eggs hatched
No. 2 EPMO	1	30	12	83	83	100	..	..	..	..	..	..	..	..	...
No. 3 EPMO	½	30	12	16	75	92	100	..	..	..	..	..	..	..	...
No. 4 EPMO	⅓	30	12	33	66	100	..	..	..	..	..	..	..	..	...
No. 5 EPMO	¼	30	12	16	41	58	83	92	92	92	100	..	..	13	100
No. 6 EPMO	⅛	30	12	0	0	0	0	8	8	16	25	41	41	83	72
No. 20 PPO	¼	14.1	9	0	55	55	55	77	88	88	100	..	..	0	...
No. 5 EPMO	¼	30	12	17	42	59	83	92	92	92	100	..	..	13	100
No. 21 WMO	¼	58.78	9	0	22	44	44	55	77	77	88	100	..	0	...
No. 26 PHM	¼	530.3	10	10	40	70	80	80	100	..	..	..	..	0	...
No. 25 Cylvalette	¼	2374.27	10	10	60	70	80	100	..	..	..	..	..	0	...
No. 27 Petrolatum	¼	.....	9	0	44	44	66	66	77	88	88	100	..	2	50
No. 15 Chlorocosane	¼	.....	10	0	0	0	0	0	10	10	20	20	20	22	100
No. 14 Chlorocosane	⅛	.....	11	0	10	10	10	10	10	10	30	30	50	8	87
No. 1 Vaseline and paraffine	..	.....	12	0	0	8	33	33	33	33	33	42	59	104	49
No. 84 Pa. crude oil	⅛	.....	10	0	40	60	60	60	100	..	..	..	..	0	...
No. 85 Pa. crude oil	⅛	.....	11	36	36	100,	..	..	..	..	..	..	..	0	...

TABLE IX—*Continued*

IMPREGNATION WITH OILS

Oils used in the experiments	No. of c.c. used to 1 sq. in.	Viscosity water = 1	No. of lice used in experiment	Percentage dead at different periods of time (hours)										No. of eggs laid	Per cent of eggs hatched
				12	24	36	48	60	72	84	96	108	120		
No. 158 Kansas crude oil	⅓	.....	10	0	30	80	80	80	80	80	80	80	80	0	...
No. 159 Okla. crude oil	⅓	.....	10	10	40	100	..	..	..	..	..	..	..	0	...
No. 174 Okla. crude oil well aired	⅓	.....	10	0	10	10	10	10	50	50	60	60	60	10	...
No. 9 Lard oil	⅓	31.51	10	0	30	30	50	50	90	90	90	90	90	1	100
No. 11 Fish oil	⅓	20	10	0	40	40	70	70	70	90	90	90	90	0	...
No. 16 Knochen oil	⅓	35.88	10	0	10	10	20	20	20	30	40	50	50	9	77
No. 10 Cottonseed oil	⅓	26.66	10	0	20	20	20	20	80	80	80	80	80	1	0
No. 17 Olive oil	⅓	31.82	9	0	0	0	0	0	0	0	11	11	22	27	52
No. 18 Peanut oil	⅓	.....	9	0	0	0	0	0	22	22	22	22	22	21	71
No. 19 Rape-seed oil	⅓	.....	9	66	100	..	..	..	..	..	..	..	..	0	...
No. 313 Rancid palm oil	⅓	.....	10	0	0	0	0	0	0	0	0	0	10	11	22
No. 7 Check	..	.....	10	0	10	10	10	20	20	20	..	..	..	43	51
No. 12 Check	..	.....	10	0	20	20	30	30	30	30	30	30	30	35	26
No. 22 Check	..	.....	9	0	0	0	0	0	11	11	11	11	11	9	74
No. 29 Check	..	.....	10	0	0	0	0	0	0	0	0	0	0	67	75

to leave oily cloth, such lice were again placed upon the cloth, at each feeding. The results were as follows:

Olive oil killed 50 per cent in 4 days
Cedar oil killed 100 per cent in 20 hours
Castor oil killed 100 per cent in 92 hours
Cod-liver oil killed 100 per cent in 68 hours
Paraffin oil killed 100 per cent in 68 hours
Liquid petrolatum killed 100 per cent in 20 hours
Rape-seed oil killed 100 per cent in 44 hours
Neat's-foot oil killed 50 per cent in 6 days
Lard oil killed 100 per cent in 116 hours
Cotton seed oil killed 50 per cent in 4 days
Commercial oleic acid killed 100 per cent in 20 hours
Raw linseed oil killed 100 per cent in 63 hours
Boiled linseed oil killed 100 per cent in 63 hours
Whale oil killed 100 per cent in 63 hours
Fish oil killed 100 per cent in 15 hours
Peanut oil killed 100 per cent in 39 hours

In these first experiments the quantity of oil was not measured. To determine the effect of definite quantities of oils, the experiments tabulated in Table IX were conducted. Different lubricating oils designated as EPMO, PPO, WMO, Cylvalette, etc., and animal and vegetable oils were used. The viscosities of these oils measured at room temperature by a stalagmometer are given, the viscosity of water being taken as 1.

The results with the oils were in general not favorable, unless a large quantity of the oil was present. The proportion of $\frac{1}{8}$ c.c. to 1 sq. in. of the cloth, which is just sufficient to make it oily to the touch, did not give good results.

Inorganic chemicals.—A number of inorganic chemicals were next studied, among which were some soluble only in water, others were oil soluble, and a few were used dissolved in PPO, a light lubricating oil. The only really effective chemical was a saturated solution of bichloride of mercury. Mr. Herbert P. Pearson, a textile expert, considering that lice are not usually found in felt hats impregnated with mercury compounds, prepared for study a number of pieces of cloth impregnated with mercury compounds. The object to be attained in his impregnation was stated to be the union of mercurous oxide or mercury metal with the keratin of the cloth. Series A was impregnated by a two-bath process on wool shirting, the mercuric chloride being applied hot and sodium formate cold, in the proportion 27:15 by weight in the same volume of water. After the two impregnations, the samples were dried on a cylinder heated to 220° F., washed in hot water, and redried. There would, therefore, be no free mercuric chloride on the cloth. Series B was impregnated by a one-bath process using mercuric chloride and acid sodium formate. Series C, D, and E were impregnations of cotton nainsook using the same process

TABLE X

IMPREGNATION WITH INORGANIC CHEMICALS

Chemical	Quantity	No. of lice	Percentage dead in different periods of time (hours) 12	24	36	48	60	72	84	96	108	120	No. of eggs laid	Per cent of eggs hatched
No. 28 Copper oleate	Sat. sol. in PPO. ½ c.c. to 1 sq. in.	9	0	0	0	11	11	22	22	33	33	33	26	27
No. 31 Zinc stearate	"	10	0	10	10	20	30	40	40	50	50	50	12	69
No. 30 Sulphur	"	10	0	20	20	20	20	20	20	20	40	50	22	95
No. 32 Sulphur	"	10	10	20	20	30	30	40	40	40	40	60	12	50
No. 331 Copper sulphate	2% Aqueous	10	0	0	0	10	10	10	10	10	10	10	7	100
No. 332 Zinc chloride	" "	10	0	0	0	0	0	0	0	20	20	30	5	80
No. 333 Ferric chloride	" "	10	10	10	30	30	40	40	40	40	40	60	1	0
No. 334 Ferrous sulphate	" "	10	0	0	0	0	20	30	30	30	30	30	0	...
No. 335 Sodium arsenite	" "	10	30	30	70	100	..	..	..	..	..	..	0	...
No. 336 Sodium hydroxide	" "	10	0	0	0	0	0	0	0	0	0	0	16	31
No. 837 Silver nitrate	" "	10	0	0	50	70	70	90	90	90	90	90	0	...
No. 340 Mercuric bichloride	Saturated aqueous	10	100	..	..	..	..	..	..	..	..	..	0	...
No. 316 Lead acetate	Saturated aqueous	10	0	30	70	80	80	80	80	80	80	90	3	0
No. 562 A1 Mercuric chloride	1:15	10	0	10	30	60	60	60	..	..	..	..	6	no record
No. 563 A2 Mercuric chloride	1:25	10	0	0	0	0	0	10	..	..	..	..	5	no record
No. 564 A3 Mercuric chloride	1:50	10	0	0	0	0	0	10	..	..	..	..	21	no record
No. 565 A4 Mercuric chloride	1:100	10	0	0	0	20	20	20	..	..	..	..	16	no record
No. 566 B1 Mercuric chloride	1:250	10	0	0	0	0	0	0	..	..	..	..	14	no record
No. 567 C1 Mercuric chloride	Cotton nainsook treated. Proportion unknown	10	0	0	0	0	10	10	..	..	..	..	19	no record

TABLE X—*Continued*

IMPREGNATION WITH INORGANIC CHEMICALS

Chemical	Quantity	No. of lice	Percentage dead in different periods of time (hours) 12	24	36	48	60	72	84	96	108	120	No. of eggs laid	Per cent of eggs hatched
No. 568 D1 Mercuric chloride	Cotton nainsook treated. Proportion unknown	10	0	0	0	0	0	0	..	..	..	..	16	no record
No. 568 E1 Mercuric chloride	Cotton nainsook treated. Proportion unknown	10	0	0	10	10	10	10	..	..	..	..	10	no record
H4 Mercuric chloride	.5% solution	5	0	10	20	20	..	..	..	..	..	..	6	no record
H5 Mercuric chloride	.2% solution.	5	0	10	10	10	..	..	..	..	..	..	1	no record
H6 Mercuric chloride	.1% solution	5	0	0	10	10	..	..	..	..	..	..	4	no record
K2 Mercuric chloride	.25% solution	5	100	..	..	..	..	..	..	..	..	..	3	no record
K2 Mercuric chloride	.25% solution	5	10	10	10	10	..	..	..	..	..	..	immature	
K4 Mercuric chloride	.2% solution	5	0	20	20	20	20	..	..	..	..	..	7	no record
L2 Mercuric chloride	.25% solution	4	0	0	0	0	..	..	..	..	..	..	3	no record
L3 Colloidal mercuric hydroxide	1-500	4	0	0	10	10	..	..	..	..	..	..	5	no record
L4 Colloidal emulsion of aluminum stearate 4% and phenol 1%	.....	4	0	0	0	10	..	..	..	..	..	..	3	no record
L5 Aluminum stearate 2% phenol ½%	.....	4	0	0	0	0	..	..	..	..	..	..	..	...
No. 29 Check	.....	10	0	0	0	0	0	0	0	0	0	0	67	75
No. 36 Check	.....	10	0	0	0	0	0	0	0	0	0	0	43	33
No. 338 Check	.....	10	0	0	0	0	0	0	10	10	10	10	61	61
No. 570 Check	.....	10	0	0	0	0	0	10	..	..	..	..	12	no record

as Series B. The strength of the solutions used was not given except that the K series was considered a better impregnation than the H series Nothing is known of the L series other than the data given in the table.

The results of these impregnations were not favorable, possibly due to the chemical union of the mercury with the keratin. To be effective, the mercury salt would have to be free, and in such a state would be too dangerous to be worn by the soldier. The observation that the clothes louse is seldom found upon felt hats is no doubt explained by the fact that the head is not their natural habitat.

Active organic chemicals dissolved in oil.—From the results of other experiments[58] it was found that oils wet and spread over the chitinous exoskeleton of the insect, hence it would appear that if an active chemical was dissolved in the oil this chemical would be brought into closer contact with the chitin and would have a better opportunity of penetrating and causing the death of the insect. This series contained organic acids, derivatives containing iodine, alkaloids, and organic bases; anthracene and other hydrocarbons usually found with it,[59] naphthalene and naphthalene derivatives, nitro and hydroxyl derivatives, and a few general chemicals classified as sweet-smelling aromatics. The chemicals were dissolved in light lubricating oils and except where the chemical was quite soluble in the oil, a saturated solution was used. To insure obtaining a saturated solution, the oil and chemical were warmed somewhat and then allowed to cool. The undissolved chemicals often held in suspension by the cool oil were thrown down by centrifuging for a few minutes. An even distribution of the oil over the cloth was obtained by dissolving the required amount of the oil solution in ether and then applying the ether solution to the underwear. In a few minutes the ether evaporated, leaving the oil and chemical on the cloth. The treated underwear was then cut into small pieces, placed in a vial 2½ x 1 inch, the lice added and the open vial placed in the incubator. Every 12 hours they were examined, and the living lice fed. When all the lice were dead in an experiment, they were removed and the uncovered vial remained on the laboratory table until the experiment was repeated. By thus conducting a number of experiments with the same piece of underwear, it was hoped to obtain some idea of the lasting properties of the chemicals as well as their toxicity. (Table XI.) Some of the preparations killed during the first day or two, after which they failed to kill, the oil being left without its toxic principle, due to the evaporation of the chemical. Other cases may be noted where a relatively non-volatile chemical killed quickly during the first day or two, after which it killed slowly or not at all. Such results were due to more volatile impurities which evaporated, leaving the less volatile and slow-killing chemical behind.

[58] Physical Properties Governing the Efficacy of Contact Insecticides.

[59] Dr. F. W. Sperr kindly supplied a number of by-products of the manufacture of coke for use in these experiments.

TABLE XI

IMPREGNATION WITH ACTIVE CHEMICALS DISSOLVED IN OILS

	Total	Percentage dead in hours									Total eggs	Per cent hatched
		12	24	36	48	60	72	84	96	108	120		
Organic acids													
No. 108 Salicylic acid sat. sol. in EPMO 1 c.c.—8 sq. in.	10	90	100	..	..	..	..	..	..	..	..	0	..
No. 132 No. 108, 24 hours old	10	0	70	90	90	90	90	90	90	90	90	0	..
No. 111 Oleic acid in WMO—5% 1 c.c.—8 sq. in.	10	0	0	0	0	10	10	10	10	10	20	36	61
No. 58 Valeric acid 3 c.c. in 3 c.c. EPMO 1 c.c.—8 sq. in.	10	100	..	..	..	..	..	..	..	..	..	0	..
No. 62 No. 58, 24 hrs. old	10	100	..	..	..	..	..	..	..	..	..	0	..
No. 63 No. 58, 48 hrs. old	10	70	80	90	90	90	90	90	90	90	90	0	..
No. 170 Cinnamic acid in PPO sat. sol. 1 c.c.—8 sq. in.	10	0	0	0	0	0	0	0	0	0	0	10	91.6
Iodine derivatives													
No. 34 Iodoform in PPO sat. sol. 1 c.c.—8 sq. in.	10	100	..	..	..	..	..	..	..	..	..	0	..
No. 38 No. 34, 24 hrs. old	10	90	100	..	..	..	..	..	..	..	..	0	..
No. 43 No. 34, 48 hrs. old	10	100	..	..	..	..	..	..	..	..	..	0	..
No. 47 No. 34, 72 hrs. old	10	10	70	70	90	100	..	..	..	..	..	0	..
No. 51 No. 34, 120 hrs. old	10	0	80	80	80	90	90	100	..	..	..	0	..
No. 64 No. 34, 216 hrs. old	10	0	0	0	80	80	100	..	..	..	..	0	..
No. 102 No. 34, 384 hrs. old	10	0	20	60	80	90	100	..	..	..	..	0	..
No. 189 No. 34, 720 hrs. old	10	0	10	10	50	90	90	90	90	90	90	0	..
No. 119 Phenyl iodide in WMO 1 c.c.—8 sq. in.	10	100	..	..	..	..	..	..	..	..	..	0	..
No. 134 No. 119, 24 hrs. old	10	0	0	0	50	70	90	90	90	90	90	0	..
No. 185 Thymol iodide in PPO sat. sol. 1 c.c.—8 sq. in.	10	0	0	0	0	0	0	0	20	20	20	immature	
Alkaloids and organic bases													
No. 39 Cinchonine in PPO sat. sol. 1 c.c.—8 sq. in.	10	0	0	0	10	30	30	30	30	30	30	16	63
No. 54 Morphine in EPMO sat. sol. 1 c.c.—8 sq. in.	10	0	0	10	10	10	10	10	20	20	30	13	23
No. 56 Strychnine in EPMO sat. sol. 1 c.c.—8 sq. in.	12	0	0	0	0	0	8	8	8	8	11	11	22
No. 55 Urea in EPMO sat. sol. 1 c.c.—8 sq. in.	12	0	0	0	0	0	0	0	42	42	50	4	50
Anthracene and related compounds													
No. 75 Anthracene c.p. in EPMO sat. sol. 1 c.c.—8 sq. in.	10	0	0	0	0	0	0	0	0	0	0	8	62.5
No. 74 Anthracene c.p. in EPMO sat. sol. 1 c.c.—8 sq. in.	10	10	10	20	20	40	40	40	50	60	60	0	..
No. 69 Anthracene crude sat. sol. EPMO 1 c.c.—8 sq. in.	10	100	..	..	..	..	..	..	..	..	..	0	..
No. 78 No. 69 24 hrs. old	10	0	100	..	..	..	..	..	..	..	..	0	..
No. 81 No. 69 48 hrs. old	10	100	..	..	..	..	..	..	..	..	..	0	..
No. 87 No. 69 72 hrs. old	10	100	..	..	..	..	..	..	..	..	..	0	..
No. 95 No. 69 96 hrs. old	10	0	90	90	100	..	..	..	..	..	..	0	..
No. 118 No. 69 118 hrs. old	10	0	70	70	100	..	..	..	..	..	..	0	..
No. 156 No. 69 264 hrs. old	5	20	40	40	60	80	80	80	100	..	..	0	..

TABLE XI—*Continued*

IMPREGNATION WITH ACTIVE CHEMICALS DISSOLVED IN OILS

No.	Anthracene and related compounds	Total	Percentage dead in hours 12	24	36	48	60	72	84	96	108	120	Total eggs	Per cent hatched
90	Dry crude anthracene in crude oil Pa. 1 c.c.—8 sq. in.	10	100	..	..	..	..	..	..	..	..	..	0	..
99	No. 90 24 hrs. old	10	100	..	..	..	..	..	..	..	..	..	0	..
68	Anthracene oil 5% in EPMO 1 c.c.—8 sq. in.	10	100	..	..	..	..	..	..	..	..	..	0	..
77	No. 68 24 hrs. old	10	0	100	..	..	..	..	..	..	..	..	0	..
82	No. 68 48 hrs. old	10	100	..	..	..	..	..	..	..	..	..	0	..
88	No. 68 72 hrs. old	10	100	..	..	..	..	..	..	..	..	..	0	..
96	No. 68 96 hrs. old	10	0	40	60	100	..	..	..	..	..	..	0	..
117	No. 68 168 hrs. old	10	0	70	70	100	..	..	..	..	..	..	0	..
155	No. 68 264 hrs. old	5	0	40	100	..	..	..	..	..	..	..	0	..
172	No. 68 360 hrs. old	10	0	0	0	10	10	20	20	30	60	60	12	0
19	Residue from Alc. ext. of crude anthracene in EPMO sat. sol. 1 c.c.—8 sq. in.	10	100	..	..	..	..	..	..	..	..	..	0	..
91	1st Alc. ext. of crude anthracene in EPMO 1 c.c.—8 sq. in.	10	100	..	..	..	..	..	..	..	..	..	0	..
100	3d Alc. ext. in EPMO 1 c.c.—8 sq. in.	10	100	..	..	..	..	..	..	..	..	..	0	..
100A	No. 100 24 hrs. old	10	100	..	..	..	..	..	..	..	..	..	0	..
94	Residue from caustic potash extraction in EPMO 1 c.c.—8 sq. in.	10	100	..	..	..	..	..	..	..	..	..	0	..
104	Caustic potash extract of crude anthracene in EPMO 1. c.c. —8 sq. in.	10	0	0	10	70	70	70	70	70	70	70	0	..
175	Residue from H_2SO_4 extraction in PPO 1 c.c.—8 sq. in	10	100	..	..	..	..	..	..	..	..	..	0	..
211	H_2SO_4 Extract of crude anthracene in PPO 1 c.c.—8 sq. in.	10	10	50	70	100	..	..	..	..	..	..	0	..
70	Diphenyl sat. sol. in EPMO 1 c.c.—8 sq. in.	10	0	100	..	..	..	..	..	..	..	..	0	..
79	No. 70 24 hrs. old	10	0	100	..	..	..	..	..	..	..	..	0	..
83	No. 70 48 hrs. old	10	0	60	80	90	90	100	..	..	..	..	0	..
106	No. 70 96 hrs. old	10	90	100	..	..	..	..	..	..	..	..	0	..
126	No. 70 168 hrs. old	10	90	90	100	..	..	..	..	..	..	..	0	..
161	No. 70 288 hrs. old	10	0	70	100	..	..	..	..	..	..	..	0	..
171	No. 70 360 hrs. old	10	0	30	40	90	90	90	100	..	..	..	0	..
71	Paracoumarene sat. sol. in EPMO 1 c.c.—8 sq. in.	10	0	0	0	0	0	0	20	20	50	50	18	..
73	Coal tar oil 10% in EPMO 1 c.c.—8 sq. in.	10	100	..	..	..	..	..	..	..	..	..	0	..
73A	No. 73 24 hrs. old	10	100	..	..	..	..	..	..	..	..	..	0	..
80	No. 73 48 hrs. old	10	100	..	..	..	..	..	..	..	..	..	0	..
86	No. 73 72 hrs. old	10	100	..	..	..	..	..	..	..	..	..	0	..
97	No. 73 96 hrs. old	10	0	90	100	..	..	..	..	..	..	..	0	..

TABLE XI—*Continued*

IMPREGNATION WITH ACTIVE CHEMICALS DISSOLVED IN OILS

	Total	Percentage dead in hours									Total eggs	Per cent hatched
		12	24	36	48	60	72	84	96	108	120		
Anthracene and related compounds													
No.													
116 No. 73 168 hrs. old	10	0	70	90	100	..	..	..	..	..	..	0	..
162 No. 73 288 hrs. old	10	0	50	50	60	100	..	..	..	..	..	0	..
176 No. 73 384 hrs. old	10	0	0	0	0	20	30	60	60	60	80	0	..
114 10% Alkaline ext. of low tar B.P. 270°–365° in WMO 1 c.c. —8 sq. in	10	100	..	..	..	..	..	..	..	..	..	0	..
129 No. 114 24 hrs. old	10	100	..	..	..	..	..	..	..	..	..	0	..
142 No. 114 72 hrs. old	10	100	..	..	..	..	..	..	..	..	..	0	..
152 No. 114 96 hrs. old	5	100	..	..	..	..	..	..	..	..	..	0	..
166 No. 114 168 hrs. old	10	80	100	..	..	..	..	..	..	..	..	0	..
177 No. 114 216 hrs. old	10	30	100	..	..	..	..	..	..	..	..	0	..
194 No. 114 264 hrs. old	10	50	100	..	..	..	..	..	..	..	..	0	..
205 No. 114 312 hrs. old	10	70	70	100	..	..	..	..	..	..	..	0	..
219 No. 114 360 hrs. old	10	0	90	90	90	90	90	90	90	90	90	0	..
Naphthalene and derivatives													
13 10% Naph. in PPO 1 c.c.—8 sq. in	10	100	..	..	..	..	..	..	..	..	..	0	..
23 No. 13 24 hrs. old	10	0	0	10	20	30	30	30	60	70	70	22	82
33 Alpha naphthylamine sat. sol. in PPO 1 c.c.—8 sq. in	10	100	..	..	..	..	..	..	..	..	..	0	..
41 No. 33 48 hrs. old	10	100	..	..	..	..	..	..	..	..	..	0	..
45 No. 33 72 hrs. old	10	100	..	..	..	..	..	..	..	..	..	0	..
49 No. 33 96 hrs. old	10	100	..	..	..	..	..	..	..	..	..	0	..
52 No. 33 120 hrs. old	10	100	..	..		..	..	..	..	..	..	0	..
60 No. 33 144 hrs. old	10	100	..	..	..	..	..	..	..	..	..	0	..
65 No. 33 216 hrs. old	10	100	..	..	..	..	..	..	..	..	..	0	..
69 No. 33 240 hrs. old	10	100	..	..	..	..	..	..	..	..	..	0	..
103 No. 33 384 hrs. old	10	0	0	100	..	..	..	..	..	..	..	0	..
125 No. 33 456 hrs. old	10	100	..	..	..	..	..	..	..	..	..	0	..
188 No. 33 720 hrs. old	10	0	100	..	..	..	..	..	..	..	..	0	..
76 Sulphonated naphthalene sat. sol. EPMO 1 c.c.—8 sq. in.	10	0	0	0	0	10	30	30	30	30	30	2	100
105 Tetrachlornaphthalene (add comp) in WMO 1 c.c.—8 sq. in.	10	0	30	30	60	70	80	80	100	..	..	0	..
186 Chlorinated naphthalene in PPO 1 c.c.—8 sq. in	10	0	0	10	20	20	90	90	90	90	100	Imm.	..
225 No. 186 168 hrs. old	10	0	0	10	10	10	20	40	40	40	40	0	..
196 Dichlorinated naphthalene in PPO 1 c.c.—8 sq. in	10	60	100	..	..	..	..	..	..	..	..	0	..
207 No. 196 48 hrs. old	10	40	100	..	..	..	..	..	..	..	..	0	..
222 No. 196 96 hrs. old	10	10	100	..	..	..	..	..	..	..	..	0	..

TABLE XI—*Continued*

IMPREGNATION WITH ACTIVE CHEMICALS DISSOLVED IN OILS

	Total	Percentage dead in hours										Total eggs	Per cent hatched
		12	24	36	48	60	72	84	96	108	120		
Naphthalene and derivatives													
No.													
229 No. 196 144 hrs. old	10	0	0	70	100	..	..	..	..	..	..	0	..
247 No. 196 240 hrs. old	10	30	90	100	..	..	..	..	..	..	..	0	..
286 No. 196 336 hrs. old	10	60	60	100	..	..	..	..	..	..	..	0	..
110 Betanaphthol sat. sol. WMO 1 c.c.—8 sq. in	10	0	100	..	..	..	..	..	..	..	..	0	..
136 No. 110 24 hrs. old	10	10	10	10	60	60	100	..	..	..	..	0	..
109 Alphanaphthol sat. sol. WMP 1 c.c.—8 sq. in	10	90	100	..	..	..	..	..	..	..	..	0	..
135 No. 109 24 hrs. old	10	0	100	..	..	..	..	..	..	..	..	0	..
154 No. 109 96 hrs. old	5	100	..	..	..	..	..	..	..	..	..	0	..
163 No. 109 168 hrs. old	10	10	90	100	..	..	..	..	..	..	..	0	..
178 No. 109 216 hrs. old	10	0	70	70	100	..	..	..	..	..	..	0	..
199 No. 109 288 hrs. old	10	10	100	..	..	..	..	..	..	..	..	0	..
210 No. 109 336 hrs. old	10	0	100	..	..	..	..	..	..	..	..	0	..
218 No. 109 360 hrs. old	10	0	100	..	..	..	..	..	..	..	..	0	..
253 No. 109 528 hrs. old	10	0	60	80	90	90	100	..	..	..	..	0	..
Nitro compounds													
57 Paranitrophenol sat. sol. in EPMO 1 c.c.—8 sq. in	10	0	0	0	0	0	0	0	0	0	0	68	35
24 Ortho nitranilin sat. sol. in PPO 1 c.c.—8 sq. in	10	100	..	..	..	..	..	..	..	..	..	0	..
35 No. 24 24 hrs. old	10	80	100	..	..	..	..	..	..	..	..	0	..
37 No. 24 48 hrs. old	10	80	100	..	..	..	..	..	..	..	..	0	..
44 No. 24 72 hrs. old	10	100	..	..	..	..	..	..	..	..	..	0	..
48 No. 24 96 hrs. old	10	100	..	..	..	..	..	..	..	..	..	0	..
50 No. 24 120 hrs. old	10	100	..	..	..	..	..	..	..	..	..	0	..
53 No. 24 144 hrs. old	10	0	100	..	..	..	..	..	..	..	..	0	..
61 No. 24 168 hrs. old	10	0	100	..	..	..	..	..	..	..	..	0	..
66 No. 24 240 hrs. old	10	0	90	100	..	..	..	..	..	..	..	0	..
101 No. 24 408 hrs. old	10	0	80	100	..	..	..	..	..	..	..	0	..
130 No. 24 480 hrs. old	10	70	70	70	80	80	80	80	80	90	90	0	..
107 No. 24 432 hrs. old WMO oil 1 c.c.—8 sq. in	10	40	40	50	100	..	..	..	..	..	..	0	..
Sweet-smelling aromatic compounds													
112 Coumarin sat. sol. in WMO 1 c.c.—8 sq. in	10	100	..	..	..	..	..	..	..	..	..	0	..
131 No. 112 24 hrs. old	10	100	..	..	..	..	..	..	..	..	..	0	..
147 No. 112 72 hrs. old	10	90	100	..	..	..	..	..	..	..	..	0	..
160 No. 112 120 hrs. old	10	60	100	..	..	..	..	..	..	..	..	0	..

TABLE XI—*Continued*

IMPREGNATION WITH ACTIVE CHEMICALS DISSOLVED IN OILS

	Total	Percentage dead in hours									Total eggs	Per cent hatched
		12	24	36	48	60	72	84	96	108	120		
Sweet-smelling aromatic compounds													
No.													
173 No. 112 192 hrs. old	10	0	100	..	..	..	..	..	..	..	..	0	..
183 No. 112 240 hrs. old	10	0	70	80	80	90	90	100	..	..	..	0	..
208 No. 112 336 hrs. old	10	0	100	..	..	..	..	..	..	..	..	0	..
217 No. 112 360 hrs. old	10	0	90	100	..	..	..	..	..	..	..	0	..
252 No. 112 528 hrs. old	10	20	40	80	100	..	..	..	..	..	..	0	..
195 Vanillin sat. sol. in PPO 1 c.c.—8 sq. in	10	0	0	0	0	10	10	10	10	10	20	0	..
121 Heliotropine sat. sol. in WMO 1 c.c.—8 sq. in	10	100	..	..	..	..	..	..	..	..	..	0	..
133 No. 121 24 hrs. old	10	100	..	..	..	..	..	..	..	..	..	0	..
145 No. 121 72 hrs. old	10	100	..	..	..	..	..	..	..	..	..	0	..
153 No. 121 96 hrs. old	5	100	..	..	..	..	..	..	..	..	..	0	..
165 No. 121 168 hrs. old	10	100	..	..	..	..	..	..	..	..	..	0	..
182 No. 121 216 hrs. old	10	100	..	..	..	..	..	..	..	..	..	0	..
190 No. 121 264 hrs. old	10	100	..	..	..	..	..	..	..	..	..	0	..
201 No. 121 312 hrs. old	10	100	..	..	..	..	..	..	..	..	..	0	..
214 No. 121 360 hrs. old	10	100	..	..	..	..	..	..	..	..	..	0	..
249 No. 121 528 hrs. old	10	100	..	..	..	..	..	..	..	..	..	0	..
Phenols and phenol derivatives													
123 10% creosote in WMO 1 c.c.—8 sq. in	10	100	..	..	..	..	..	..	..	..	..	0	..
139 No. 123 24 hrs. old	10	100	..	..	..	..	..	..	..	..	..	0	..
143 No. 123 72 hrs. old	10	100	..	..	..	..	..	..	..	..	..	0	..
149 No. 123 96 hrs. old	5	100	..	..	..	..	..	..	..	..	..	0	..
168 No. 123 168 hrs. old	10	100	..	..	..	..	..	..	..	..	..	0	..
180 No. 123 216 hrs. old	10	90	100	..	..	..	..	..	..	..	..	0	..
191 No. 123 264 hrs. old	10	80	100	..	..	..	..	..	..	..	..	0	..
204 No. 123 312 hrs. old	10	100	..	..	..	..	..	..	..	..	..	0	..
216 No. 123 360 hrs. old	10	80	100	..	..	..	..	..	..	..	..	0	..
251 No. 123 528 hrs. old	10	40	40	90	90	90	100	..	..	..	..	0	..
122 10% creosote 10% oleic acid in WMO 1 c.c.—8 sq. in	10	100	..	..	..	..	..	..	..	..	..	0	..
140 No. 122 24 hrs. old	10	100	..	..	..	..	..	..	..	..	..	0	..
146 No. 122 72 hrs. old	10	100	..	..	..	..	..	..	..	..	..	0	..
150 No. 122 96 hrs. old	5	100	..	..	..	..	..	..	..	..	..	0	..
167 No. 122 168 hrs. old	10	100	..	..	..	..	..	..	..	..	..	0	..
181 No. 122 216 hrs. old	10	40	100	..	..	..	..	..	..	..	..	0	..
192 No. 122 264 hrs. old	10	70	100	..	..	..	..	..	..	..	..	0	..
203 No. 122 312 hrs. old	10	100	..	..	..	..	..	..	..	..	..	0	..

TABLE XI—*Continued*

IMPREGNATION WITH ACTIVE CHEMICALS DISSOLVED IN OILS

PHENOLS AND PHENOL DERIVATIVES	TOTAL	PERCENTAGE DEAD IN HOURS 12	24	36	48	60	72	84	96	108	120	TOTAL EGGS	PER CENT HATCHED
No.													
215 No. 122 360 hrs. old	10	70	100	..	..	..	..	..	..	..	..	0	..
250 No. 122 528 hrs. old	10	20	50	60	80	80	90	100	..	..	..	0	..
113 Pearson's creolin in WMO 10% sol. 1 c.c.—8 sq. in	10	100	..	..	..	..	..	..	..	..	..	0	..
128 No. 113 24 hrs. old	10	100	..	..	..	..	..	..	..	..	..	0	..
151 No. 113 96 hrs. old	5	100	..	..	..	..	..	..	..	..	..	0	..
164 No. 113 168 hrs. old	10	100	..	..	..	..	..	..	..	..	..	0	..
171 No. 113 216 hrs. old	10	80	100	..	..	..	..	..	..	..	..	0	..
193 No. 113 264 hrs. old	10	100	..	..	..	..	..	..	..	..	..	0	..
202 No. 113 312 hrs. old	10	100	..	..	..	..	..	..	..	..	..	0	..
213 No. 113 360 hrs. old	10	70	100	..	..	..	..	..	..	..	..	0	..
248 No. 113 528 hrs. old	10	40	50	50	60	100	..	..	..	..	..	0	..
198 Tricresol 10% sol. in PPO 1 c.c.—8 sq. in	10	100	..	..	..	..	..	..	..	..	..	0	..
209 No. 198 48 hrs. old	10	100	..	..	..	..	..	..	..	..	..	0	..
221 No. 198 96 hrs. old	10	100	..	..	..	..	..	..	..	..	..	0	..
227 No. 198 144 hrs. old	10	100	..	..	..	..	..	..	..	..	..	0	..
246 No. 198 240 hrs. old	10	100	..	..	..	..	..	..	..	..	..	0	..
365 No. 198 288 hrs. old	10	100	..	..	..	..	..	..	..	..	..	0	..
109 Alphanaphthol sat. sol. in WMO 1 c.c.—8 sq. in	10	90	100	..	..	..	..	..	..	..	..	0	..
Betanaphthol. See under Naphthalene Comp.													
120 Guaiacol carbonate sat. sol. in WMO 1 c.c.—8 sq. in	10	0	0	0	10	20	20	20	20	20	30	64	39
148 Phenyl salicylate 25% sol. in PPO 1 c.c.—8 sq. in	10	0	40	60	100	..	..	..	..	..	..	0	..
Phenyl iodide. See under Iodine.													
Thymol iodide. See under Iodine.													
197 Tribromphenol sat. sol. in PPO 1 c.c.—8 sq. in	10	100	..	..	..	..	..	..	..	..	..	0	..
206 No. 197 48 hrs. old	10	10	100	..	..	..	..	..	..	..	..	0	..
223 No. 197 96 hrs. old	10	60	100	..	..	..	..	..	..	..	..	0	..
228 No. 197 144 hrs. old	10	0	100	..	..	..	..	..	..	..	..	0	..
236 No. 197 192 hrs. old	10	0	100	..	..	..	..	..	..	..	..	0	..
245 No. 197 197 hrs. old	10	0	40	40	90	100	..	..	..	..	..	0	..
57 Paranitrophenol sat. sol. in EPMO 1 c.c.—8 sq. in	10	0	0	0	0	0	0	0	0	0	0	68	35
383 Eugenol without oil	10	100	..	..	..	..	..	..	..	..	..	0	..
384 Carvacrol without oil	10	100	..	..	..	..	..	..	..	..	..	0	..
385 Thymol without oil	10	100	..	..	..	..	..	..	..	..	..	0	..
427 Orthocresol benzoate 10% in PPO	10	10	40	90	90	90	100	..	..	..	..	0	..
431 Biphenol without oil	10	0	10	10	20	20	30	30	30	30	40	35	..

TABLE XI—*Continued*

IMPREGNATION WITH ACTIVE CHEMICALS DISSOLVED IN OILS

No.	Phenols and phenol derivatives	Total	Percentage dead in hours 12	24	36	48	60	72	84	96	108	120	Total eggs	Per cent hatched
59	Check for No. 54– 58	10	0	0	0	0	0	0	0	0	0	0	60	40
72	" " " 68– 73	10	0	0	0	0	0	0	0	10	20	20	30	30
92	" " " 89– 91	10	0	10	10	20	30	30	30	30	30	30	33	67
115	" " " 109–118	10	0	0	0	10	10	10	10	20	20	20	64	55
124	" " " 119–126	10	0	0	0	10	10	10	20	20	20	20	84	49
141	" " " 131–140	10	0	0	0	0	0	10	10	10	10	10	93	68
148	" " " 142–147	10	0	0	0	20	20	20	20	20	20	20	67	82
157	" " " 149–156	10	0	0	10	10	10	10	10	10	20	20	82	85
169	" " " 163–168	10	0	0	0	0	0	0	0	0	0	0	92	80
187	" " " 183–186	10	0	0	0	10	10	20	30	30	30	30	57	72
200	" " " 195–199	10	0	0	0	0	0	0	0	10	10	10	90	87
212	" " " 206–211	10	0	0	0	0	0	0	0	0	0	0	54	82
220	" " " 213–219	10	0	0	0	10	10	10	10	10	10	10	82	64
226	" " " 221–225	10	0	0	10	10	10	10	20	20	20	20	98	79
232	" " " 227–231	10	0	0	0	0	10	10	10	10	10	20	61	92
244	" " " 241–243	10	10	10	10	20	20	20	20	20	20	20	100	86
256	" " " 245–255	10	0	0	0	0	0	0	0	0	0	10	102	84
263	" " " 257–262	10	0	0	0	0	0	0	0	0	0	0	141	84
273	" " " 265–272	10	0	0	0	0	0	0	0	10	10	20	24	96
300	" " " 298–301	10	0	0	0	0	0	0	0	0	0	0	63	13
309	" " " 301–308	10	0	0	0	10	10	10	10	10	10	40	75	44
312	" " " 310–314	10	0	0	0	0	0	0	0	0	0	0	87	68
330	" " " 321–329	10	0	0	0	0	0	0	0	10	10	10	47	66
338	" " " 331–339	10	0	0	0	0	0	0	10	10	10	10	61	61
347	" " " 343–346	10	0	10	10	10	10	10	10	10	10	10	52	90
350	" " " 348–349	10	0	0	0	0	0	0	0	0	0	0	103	71
353	" " " 351–352	10	0	0	0	0	0	10	10	10	10	10	62	58
356	" " " 354–355	10	0	0	0	0	0	0	0	0	0	0	74	61
359	" " " 357–358	10	0	0	0	0	0	0	0	0	0	0	90	53
362	" " " 360–365	10	0	0	0	0	0	0	0	0	0	10	47	23
369	" " " 366–368	10	0	0	0	0	0	0	0	0	0	0	40	68
376	" " " 375–377	10	0	0	0	0	0	0	0	0	0	0	93	54
381	" " " 378–380	10	0	0	0	0	0	0	0	0	0	0	37	38
388	" " " 384–387	20	0	0	20	20	20	20	20	20	20	20	83	30
405	" " " 400–404	20	0	0	0	0	0	0	0	0	0	0	12	25

Lasting properties when worn.—The above experiments were at best but a poor index of the lasting properties of the chemical when worn. Further data upon this point were obtained by selecting a few of the best chemicals for impregnating pieces of cloth, which were then pinned inside the experimenter's underwear and worn next to the skin. The patches were 48 square inches in size and from day to day a piece of this underwear was cut off and its toxicity to lice tested in the incubator. These experiments showed that there was a great difference in lasting properties between the previous experiments and those in which the cloth was actually worn. Further it was apparent that the light lubricating oil used in the experiments was soon taken up by the other clothing, thus greatly reducing the toxicity of the treated cloth. A number of solid, or semisolid fats and greases were used. (Table XII.) Heliotropine was one of the best chemicals, being apparently non-toxic to the skin and lasting as long as 168 hours (no. 344) when used with cocoa butter, in which it was more soluble than in the other fats. Without the oil, heliotropine killed just as rapidly, but having crystallized on the underwear it was soon rubbed off by the friction encountered in wearing.

Toxicity of chemicals with and without oil.—The experiment with heliotropine having shown the oil to be unessential to toxicity, experiments were conducted using other chemicals with and without an oil. (Table XIII.) These results show that the oil is not necessary to the action of the chemical. In a few cases, the better results obtained without the oil were due to the use of larger quantities of the chemical than could be dissolved in the oil.

Impregnation with salts of the phenols.—Since oils were found to be unessential, the question presented itself of converting certain phenols into their non-volatile sodium or calcium salts. These salts decomposed, the original phenol being slowly generated by the action of moisture and carbon dioxide given off by the body. These salts were used to impregnate pieces of underwear which, when dry, were worn as in the previous experiments. When the patches had been worn about 5 or 6 days, it was found necessary to exercise sufficiently to produce perspiration before the phenols were present in large enough quantity to prove toxic to the lice. Thymol, carvacrol, and eugenol were studied to determine if the use of a less volatile phenol would have any influence on the period of effectiveness, but no such influence was noted. Experiments nos. 433 and 437 conducted during the summer show that the phenates are rapidly broken up and will last but 3 days during warm weather.

Bacot's[60] crude phenol soap preparation, which is no doubt a phenate, was tested. Since this preparation has been given field trials, a comparison of the results of these methods with the results in the field could

[60] The Use of Insecticides against Lice.

TABLE XII

LASTING PROPERTIES WHEN WORN

No.	Chemical	Total	Percentage dead in hours									Total eggs	Per cent hatched
			12	24	36	48	60	72	84	96	108	120		
224	10% creosote in PPO. worn 48 hrs	10	0	0	0	0	0	0	0	0	0	0	Immature	
231	10% creosote in Pa. crude oil worn 24 hrs.	10	0	0	0	0	20	20	20	20	20	20	49	90
258	5 c.c. of 5% sol. of heliotropine in ether to 12 sq. in. of cloth	10	90	100	..	..	..	..	..	..	..	..	0	..
267	No. 258 worn 24 hrs.	10	100	..	..	..	..	..	..	..	..	..	0	..
274	No. 258 worn 48 hrs.	10	100	..	..	..	..	..	..	..	..	..	0	..
280	No. 258 worn 72 hrs.	10	10	70	70	80	80	80	80	80	80	80	0	..
289	No. 258 worn 120 hrs.	10	0	0	0	0	0	0	0	10	10	10	30	..
259	5 c.c. of 5% sol. of heliotropine in ether and 5 grams of cocoa butter	10	100	..	..	..	..	..	..	..	..	..	0	..
268	No. 259 worn 24 hrs.	10	100	..	..	..	..	..	..	..	..	..	0	..
275	No. 259 worn 48 hrs.	10	100	..	..	..	..	..	..	..	..	..	0	..
281	No. 259 worn 72 hrs.	10	100	..	..	..	..	..	..	..	..	..	0	..
290	No. 259 worn 120 hrs.	10	0	0	0	0	0	0	0	0	0	0	18	6
260	5 c.c. of 5% sol. of heliotropine in ether and 5 grams of spermaceti	10	90	100	..	..	..	..	..	..	..	..	0	..
269	No. 260 worn 24 hrs	10	100	..	..	..	..	..	..	..	..	..	0	..
276	No. 260 worn 48 hrs.	10	90	100	..	..	..	..	..	..	..	..	0	..
282	No. 260 worn 72 hrs.	10	100	..	..	..	..	..	..	..	..	..	0	..
291	No. 260 worn 120 hrs	10	0	0	10	10	10	10	10	10	10	10	45	9
261	5 c.c. of 5% heliotropine in ether and 5 grams of vaseline	10	100	..	..	..	..	..	..	..	..	..	0	..
270	No. 261 worn 24 hrs	10	100	..	..	..	..	..	..	..	..	..	0	..
277	No. 261 worn 48 hrs	10	70	100	..	..	..	..	..	..	..	..	0	..
283	No. 261 worn 72 hrs.	10	90	100	..	..	..	..	..	..	..	..	0	..
292	No. 261 worn 120 hrs.	10	0	0	0	0	0	0	0	0	0	0	30	3
262	5 c.c. of 5% sol. of heliotropine in ether and 5 grams of beeswax	10	100	..	..	..	..	..	..	..	..	..	0	..
271	No. 262 worn 24 hrs	10	100	..	..	..	..	..	..	..	..	..	0	..
278	No. 262 worn 48 hrs	10	50	60	100	..	..	..	..	..	..	..	0	..
284	No. 262 worn 72 hrs.	10	100	..	..	..	..	..	..	..	..	..	0	..
293	No. 262 worn 120 hrs	10	0	0	30	30	30	30	30	30	30	30	1	..
264	5 c.c. of 5% of sol. of heliotropine in ether and 1 c.c. of cylvalette	10	100	..	..	..	..	..	..	..	..	..	0	..
272	No. 264 worn 24 hrs	10	100	..	..	..	..	..	..	..	..	..	0	..
279	No. 264 worn 48 hrs	10	80	90	100	..	..	..	..	..	..	..	0	..
285	No. 264 worn 72 hrs	10	70	80	80	90	90	90	90	90	90	90	0	..

TABLE XII—*Continued*

LASTING PROPERTIES WHEN WORN

No.	Chemical	Total	Percentage dead in hours									Total eggs	Per cent hatched
			12	24	36	48	60	72	84	96	108	120		
294	No. 264 worn 120 hrs.	10	0	0	0	0	0	0	0	0	0	0	20	15
298	20 c.c. of 5% sol. of heliotropine to 48 sq. in. of cloth worn 48 hrs.	10	70	70	100	..	..	..	..	..	..	..	0	..
299	5% heliotropine in 10 c.c. of Pa. crude oil in 20 c.c. CS_2 benzene mixture	10	70	70	100	..	..	..	..	..	..	..	0	..
	Records for 310 at 24 and 48 hr. periods lost													
310	1 gram heliotropine 5 grams cocoa butter dissolved in ether to 48 sq. in. cloth worn 72 hrs.	10	90	100	..	..	..	..	..	..	..	..	0	..
319	No. 310 worn 96 hrs	10	100	..	..	..	..	..	..	..	..	..	0	..
324	No. 310 worn 120 hrs	10	30	40	60	80	90	90	90	90	100	..	0	..
342	No. 310 worn 144 hrs	10	10	90	90	90	90	90	90	90	90	100	0	..
343	No. 310 worn 168 hrs	10	10	40	40	50	60	60	60	60	90	90	0	..
	Records for 311 at 24 and 48 hr. periods lost													
311	1 gram of heliotropine 3 grams cocoa butter in ether to 48 sq. in. worn 72 hrs.	10	90	100	..	..	..	..	..	..	..	..	0	..
318	No. 311 worn 96 hrs	10	100	..	..	..	..	..	..	..	..	..	0	..
323	No. 311 worn 120 hrs	10	80	100	..	..	..	..	..	..	..	..	0	..
341	No. 311 worn 144 hrs	10	20	100	..	..	..	..	..	..	..	..	0	..
344	No. 311 worn 168 hrs	10	0	90	100	..	..	..	..	..	..	..	0	..

TABLE XIII

IMPREGNATION WITH AND WITHOUT OILS

No.	Compounds used without oil	Total	Percentage dead in hours									Total eggs	Per cent hatched
			12	24	36	48	60	72	84	96	108	120		
234	Heliotropine without oil	10	100	..	..	..	..	..	..	..	..	..	0	..
237	No. 234 48 hrs. old	10	100	..	..	..	..	..	..	..	..	..	0	..
254	No. 234 96 hrs. old	10	100	..	..	..	..	..	..	..	..	..	0	..
238	Orthonitranilin without oil	10	0	70	70	70	70	80	80	80	80	80	0	..
302	Benzidine with PPO. 1 c.c.—8 sq. in.	10	0	0	0	0	0	0	0	0	10	20	17	88
301	Benzidine without oil	10	0	0	10	10	10	20	20	30	30	40	12	0
368	Resorcinol sat. sol. in PPO. 1 c.c.—8 sq. in.	10	0	10	20	20	20	20	20	20	20	20	8	..
372	Resorcinol without oil	10	30	40	60	60	60	70	80	80	90	90	0	..
375	Betanaphthol without oil	10	20	70	70	80	80	80	80	80	90	100	0	..
380	Alphanaphthol without oil	10	10	80	90	90	90	100	..	..	..	..	0	..
109	Alphanaphthol sat. sol. in WMO 1 c.c.—8 sq. in.	10	90	100	..	..	..	..	..	..	..	..	0	..
110	Naphthol sat. sol. in WMO 1 c.c.—8 sq. in.	10	10	10	10	60	60	100	..	..	..	..	0	..

TABLE XIV

IMPREGNATION WITH PHENATES

No.	Chemical	Total	Percentage dead in hours										Total eggs	Per cent hatched
			12	24	36	48	60	72	84	96	108	120		
322	3% NaOH + 12% creosote ½ c.c. per sq. in	10	100	..	..	..	..	..	..	..	..	..	0	..
345	No. 322 worn 24 hrs	10	100	..	..	..	..	..	..	..	..	..	0	..
348	No. 322 worn 48 hrs	10	100	..	..	..	..	..	..	..	..	..	0	..
351	No. 322 worn 72 hrs	10	40	100	..	..	..	..	..	..	..	..	0	..
354	No. 322 worn 96 hrs	10	100	..	..	..	..	..	..	..	..	..	0	..
357	No. 322 worn 120 hrs	10	60	100	..	..	..	..	..	..	..	..	0	..
360	No. 322 worn 144 hrs	10	60	100	..	..	..	..	..	..	..	..	0	..
366	No. 322 worn 168 hrs	10	0	0	10	40	60	80	80	90	90	100	0	..
370	No. 322 worn 192 hrs	10	100	..	..	..	..	..	..	..	..	..	0	..
373	No. 322 worn 216 hrs	10	100	..	..	..	..	..	..	..	..	..	0	..
378	No. 322 worn 240 hrs	10	0	10	20	30	90	100	..	..	..	..	0	..
321	3% NaOH extract of low tar. ½ c.c. per sq. in	10	100	..	..	..	..	..	..	..	..	..	0	..
346	No. 321 worn 24 hrs	10	30	100	..	..	..	..	..	..	..	..	0	..
349	No. 321 worn 48 hrs	10	60	100	..	..	..	..	..	..	..	..	0	..
352	No. 321 worn 72 hrs	10	30	100	..	..	..	..	..	..	..	..	0	..
355	No. 321 worn 96 hrs	10	10	100	..	..	..	..	..	..	..	..	0	..
358	No. 321 worn 120 hrs	10	10	100	..	..	..	..	..	..	..	..	0	..
361	No. 321 worn 144 hrs	10	100	..	..	..	..	..	..	..	..	..	0	..
367	No. 321 worn 168 hrs	10	0	20	30	30	40	80	80	80	80	90	1	0
371	No. 321 worn 192 hrs	10	10	10	20	50	90	90	90	90	90	90	0	..
374	No. 321 worn 216 hrs	10	90	100	..	..	..	..	..	..	..	..	0	..
379	No. 321 worn 240 hrs	10	40	40	40	40	50	60	100	..	..	..	0	..
385	Thymol 12 grams dissolved in 100 c.c. of 3% NaOH. cloth dipped, worn 24 hrs	10	100	..	..	..	..	..	..	..	..	..	0	..
390	No. 385 worn 48 hrs	10	100	..	..	..	..	..	..	..	..	..	0	..
393	No. 385 worn 72 hrs	10	40	90	90	100	..	..	..	..	..	..	0	..
396	No. 385 worn 96 hrs	10	30	30	100	..	..	..	..	..	..	..	0	..
400	No. 385 worn 120 hrs	10	0	50	50	90	100	..	..	..	..	..	0	..
407	No. 385 worn 144 hrs	10	0	70	100	..	..	..	..	..	..	..	0	..
410	No. 385 worn 168 hrs	10	10	10	100	..	..	..	..	..	..	..	0	..
413	No. 385 worn 192 hrs	10	0	10	100	..	..	..	..	..	..	..	0	..
416	No. 385 worn 216 hrs	10	10	..	100	..	..	..	..	..	..	..	0	..
419	No. 385 worn 240 hrs	10	0	20	30	40	50	60	70	80	80	100	0	..
432	No. 385 worn 264 hrs	10	0	0	0	10	30	60	80	90	100	..	0	..

TABLE XIV—*Continued*

IMPREGNATION WITH PHENATES

No.	Chemical	Total	Percentage dead in hours									Total eggs	Per cent hatched
			12	24	36	48	60	72	84	96	108	120		
384	Carvacrol 12 c.c. to 100 c.c. of 3% NaOH solution cloth dipped, worn 24 hrs	10	100	..	..	..	..	..	..	..	..	..	0	..
389	No. 384 worn 48 hrs	10	100	..	..	..	..	..	..	..	..	..	0	..
392	No. 384 worn 72 hrs	10	80	100	..	..	..	..	..	..	..	..	0	..
395	No. 384 worn 96 hrs	10	100	..	..	..	..	..	..	..	..	..	0	..
401	No. 384 worn 120 hrs	10	0	100	..	..	..	..	..	..	..	..	0	..
408	No. 384 worn 144 hrs	10	0	100	..	..	..	..	..	..	..	..	0	..
411	No. 384 worn 168 hrs	10	100	..	..	..	..	..	..	..	..	..	0	..
414	No. 384 worn 192 hrs	10	0	100	..	..	..	..	..	..	..	..	0	..
417	No. 384 worn 216 hrs	10	40	..	100	..	..	..	..	..	..	..	0	..
418	No. 384 worn 240 hrs	10	0	0	10	20	40	90	90	90	90	90	0	..
422	No. 384 worn 264 hrs	10	0	20	20	40	70	100	..	..	..	..	0	..
391	Eugenol 12 c.c. to 100 c.c. of 3% NaOH solution cloth dipped, worn 24 hrs	10	100	..	..	..	..	..	..	..	..	..	0	..
394	No. 391 worn 48 hrs	10	100	..	..	..	..	..	..	..	..	..	0	..
397	No. 391 worn 72 hrs	10	100	..	..	..	..	..	..	..	..	..	0	..
402	No. 391 worn 96 hrs	10	0	100	..	..	..	..	..	..	..	..	0	..
406	No. 391 worn 120 hrs	10	50	100	..	..	..	..	..	..	..	..	0	..
409	No. 391 worn 144 hrs	10	100	..	..	..	..	..	..	..	..	..	0	..
412	No. 391 worn 168 hrs	10	60	100	..	..	..	..	..	..	..	..	0	..
415	No. 391 worn 192 hrs	10	70	..	100	..	..	..	..	..	..	..	0	..
420	No. 391 worn 216 hrs	10	0	80	90	100	..	..	..	..	..	..	0	..
424	No. 391 worn 240 hrs	10	10	50	50	100	..	..	..	..	..	..	0	..
425	No. 391 worn 264 hrs	10	0	90	100	..	..	..	..	..	..	..	0	..
429	Dipped in Na creosote mixture dried and dipped in 8 c.c Pa. crude oil + 22 c.c. CS_2 to 48 sq. in. worn 92 hrs	10	0	0	0	20	20	50	50	60	70	80	0	..
433	Na creosote mixture worn 48 hrs	10	100	..	..	..	..	..	..	..	..	..	0	..
434	Same as 433 but ½ gram of paraffin MP 52° C dissolved in CS_2 and C_6H_6 added to 48 sq. in worn 48 hrs	10	100	..	..	..	..	..	..	..	..	..	0	..
435	Same as 433 but with 1 gram paraffin added worn 48 hrs	10	0	20	20	20	20	20	30	30	40	40	85	68
436	Same as 433 but with 3 grams paraffin worn 48 hrs	10	20	30	40	40	40	40	40	40	50	50	72	69
437	No. 433 worn 72 hrs	10	0	10	10	20	20	20	20	20	30	30	60	70
438	No. 434 worn 72 hrs	10	0	0	0	0	0	0	10	10	10	10	56	84

TABLE XIV—*Continued*

IMPREGNATION WITH PHENATES

No.	Chemical	Total	Percentage dead in hours									Total eggs	Per cent hatched
			12	24	36	48	60	72	84	96	108	120		
439	No. 435 worn 72 hrs.	10	0	0	0	10	10	20	30	30	40	40	27	40
440	No. 436 worn 72 hrs.	10	0	10	10	10	10	10	10	10	10	10	40	100
443	Bacot's crude phenol soap 10% phenol worn 48 hrs.	10	40	100	..	..	..	..	..	..	..	..	0	..
445	No. 443 72 hrs. (after perspiration)	10	30	60	100	..	..	..	..	..	..	..	0	..
447	No. 443 96 hrs. (after perspiration)	10	0	10	50	50	100		..	..	..	..	0	..
449	No. 443 120 hrs. (after perspiration)	10	10	10	60	60	60	60	80	80	90	90	0	..
441	3 c.c. of creosote to 48 sq. in. Clothes later dipped in 3-5% suspension of calcium hydroxide 24 hrs. old	10	40	100	..	..	..	..	..	..	..	..	0	..
442	No. 441 96 hrs. old	10	60	100	..	..	..	..	..	..	..	..	0	..
444	No. 441 120 hrs. old (after perspiration)	10	100	..	..	..	..	..	..	..	..	..	..	..
446	No. 441 144 hrs. old	10	60	80	100	..	..	..	..	..	..	..	0	..
448	No. 441 168 hrs. old (after perspiration	10	100	..	..	..	..	..	..	..	..	..	0	..
451	No. 441 192 hrs. old (after perspiration)	10	30	30	30	30	40	60	80	80	90	100	0	..

be obtained. Bacot claims that a treated shirt would retain its insecticidal action for about a week, killing more slowly as time passed, but in these experiments 96 hours appeared to be about its limit of effectiveness.

The phenates might be used to impregnate underwear for winter use, but owing to the large quantities of carbon dioxide given off in the summer, their value is greatly reduced. The search for other non-volatile chemicals which by decomposition would liberate some active pediculicide was not successful; hence a further study of volatile chemicals was undertaken.

TABLE XV

RELATIONSHIP OF BOILING POINT AND VOLATILITY TO TOXICITY

Valeric acid	184°–185°	Kills 100 per cent within 12 hrs.	
Phenyl iodide	188°.....		
Creosote	207°.....		
Naphthalene	218°.....		
Thymol	232°.....		
Carvacrol	237°.....		
Eugenol	242°.....		
Heliotropine	263°.....		
Coumarin	291° Subl.		
Diphenyl	254°.....	Kills 100 per cent within 24 hrs.	
Alphanaphthol	278°–280°		
Phenyl salicylate	172°–173°–12 mm...	Kills 60–100 per cent in 48 hrs.	
Resorcinol	276.5°.....		
Betanaphthol	285°–286°.....		
Orthocresol benzoate	293°–305°.....		
Cinnanic acid	300°.....	Very slight volatility....	Kills not more than 50 per cent in five days
Anthracene	360°.....		
Bensidine	360°.....		
Thymol iodide	not determined....		
Paranitrophenol	not determined...		
Guiacol carbonate.	Decomposes..		
Copper oleate	not determined.....	Non volatile or nearly so.	
Zinc stearate	not determined.....		

Relation of boiling point of the chemical to toxicity.—Inasmuch as other experiments with insecticides[61] have shown a relationship between the boiling point or the volatility of the chemical and the toxicity of its vapor, it was thought that a similar relationship might exist in these experiments. Table XV gives an arrangement of certain of the chemicals in such a manner as to show this relationship. In general, by increasing the boiling point, i.e., reducing the volatility, the time required to produce the death of the louse is increased. This increase is not necessarily due to a reduced toxicity, but rather to the smaller quantity of the chemical present in an atmosphere saturated with its vapor. Slightly volatile or non-volatile compounds fail to kill. It appears, therefore, that either the chemicals are unable to pass through the chitinous body-wall in any form other than a vapor, or that the chitinous body-wall is impervious to the chemical

[61] Volatility of Organic Compounds as an Index of the Toxicity of Their Vapors to Insects.

in any form, and the chemical must enter the tracheae of the louse as a vapor to reach the thin chitinous walls of the finer tracheae.

From the data thus far presented, the following principles appear to be established; first, that a successful chemical must have a fair degree of volatility to make penetration into the insect's body possible, and second, that its lasting properties depend upon a very low volatility. The best chemical, therefore, must be one of very low volatility, but of very high toxicity, in order that the small amount of vapor which would be able to penetrate the insect would bring about its death. On the other hand, such a chemical must have a low toxicity to man, as otherwise skin irritation would result.

Halogenated cresols.—Cresol and naphthalene have both received favorable notice as pediculicides, and of these two chemicals cresol appears to be the more toxic. It was therefore suggested by one of us (H.) that derivatives of cresol, especially halogenated cresols, might possess the same general toxicity of the cresol but possess a very much reduced volatility. Table XVI gives the details of the insecticidal value of these chemicals and their lasting properties when worn as in the preceding experiments. The introduction of a chlorine into the cresol molecule increases but little its lasting properties, while one bromine gives a decided increase and an iodine even a greater increase. Two chlorines are not equal to one bromine, but two bromines are greater than one iodine, while three bromines make a compound ineffective as a pediculicide. The chemicals giving the best results were the dibromorthocresol, dibrommetacresol, and the dichlor-monobrommetacresol, which last nearly two weeks. These chemicals cause a very slight irritation to the skin during the first day or two, due possibly to certain portions which have not been completely brominated. One test was made with the sodium salt of dibromtricresol, but being soluble in water, it was brought into close contact with the skin when the body was perspired, and produced somewhat more irritation than the dibromcresol itself.

The value of chlorine compounds of naphthalene having been previously studied, only the results with monobromnaphthalene, lasting 120 hours, and dibromnaphthalene, which was ineffective, are included in this table.

Determination of volatility.—Inasmuch as the boiling point of a chemical is at best but a rough index of its volatility, an effort was made to devise a simple piece of apparatus to study volatility. At first an attempt was made to study evaporation by playing a stream of air from an electric fan over weighed squares of woolen underwear of equal size, upon which the substances to be tested were dropped. The loss of weight of these squares was determined, but was not uniform. The lack of uniformity in results was due to irregularities in ventilation, owing to lack of uniformity in the air currents.

TABLE XVI

IMPREGNATION WITH HALOGENATED CRESOLS

No.	Chemical	Total	Percentage dead in hours									Total eggs	Per cent hatched
			12	24	36	48	60	72	84	96	108	120		
483	Monochlororthocresol worn 24 hrs.	5	0	0	20	20	20	20	40	40	60	60	13	0
461	Monobromparacresol worn 24 hrs.	5	100	..	..	..	..	..	..	..	..	..	0	..
465	" worn 48 hrs.	5	80	100	..	..	..	..	..	..	..	..	0	..
468	" worn 72 hrs.	5	0	40	40	60	80	80	80	80	100	..	0	..
471	" worn 96 hrs.	5	0	40	40	60	80	80	80	80	80	80	0	..
474	" worn 120 hrs.	5	20	40	40	80	100	..	..	..	..	..	0	..
477	" worn 144 hrs.	5	20	40	80	100	..	..	..	..	..	..	0	..
480	" worn 168 hrs.	5	0	0	0	0	0	20	40	40	80	80	0	..
493	Monobrommetacresol worn 24 hrs.	5	100	..	..	..	..	..	..	..	..	..	0	..
495	" worn 48 hrs.	5	100	..	..	..	..	..	..	..	..	..	0	..
497	" worn 72 hrs.	5	40	60	100	..	..	..	..	..	..	..	0	..
499	" worn 96 hrs.	5	0	0	0	0	0	0	0	0	0	20	Immature	
460	Monoiodoorthocresol worn 24 hrs.	5	100	..	..	..	..	..	..	..	..	..	0	..
464	" worn 48 hrs.	5	80	100	..	..	..	..	..	..	..	..	0	..
467	" worn 72 hrs.	5	0	100	..	..	..	..	..	..	..	..	0	..
470	" worn 96 hrs.	5	40	80	100	..	..	..	..	..	..	..	0	..
473	" worn 120 hrs.	5	100	..	..	..	..	..	..	..	..	..	0	..
476	" worn 144 hrs.	5	80	100	..	..	..	..	..	..	..	..	0	..
479	" worn 168 hrs.	5	100	..	..	..	..	..	..	..	..	..	0	..
482	" worn 192 hrs.	5	40	40	100	..	..	..	..	..	..	..	0	..
486	" worn 216 hrs.	5	0	0	20	40	60	80	80	80	80	100	5	0
490	" worn 240 hrs.	5	0	40	60	60	80	80	80	80	100	..	0	..
510	Dichlororthocresol worn 24 hrs.	5	100	..	..	..	..	..	..	..	..	..	0	..
532	" worn 48 hrs.	5	0	0	20	20	40	40	40	40	40	40	5	..
454	Dibromorthocresol worn 36 hrs.	5	100	..	..	..	..	..	..	..	..	..	0	..
456	" worn 72 hrs.	5	0	20	60	100	..	..	..	..	..	..	0	..
458	" worn 96 hrs.	5	100	..	..	..	..	..	..	..	..	..	0	..
459	" worn 120 hrs.	5	80	100	..	..	..	..	..	..	..	..	0	..
466	" worn 168 hrs.	5	0	80	100	..	..	..	..	..	..	..	0	..
472	" worn 216 hrs.	5	60	80	100	..	..	..	..	..	..	..	0	..
475	" worn 240 hrs.	5	20	100	..	..	..	..	..	..	..	..	0	..
478	" worn 264 hrs.	5	0	20	60	100	..	..	..	..	..	..	0	..
481	Dibromorthocresol worn 288 hrs.	5	20	60	80	80	80	100	..	..	..	..	0	..

TABLE XVI—*Continued*

IMPREGNATION WITH HALOGENATED CRESOLS

No.	Chemical	Total	Percentage dead in hours										Total eggs	Per cent hatched
			12	24	36	48	60	72	84	96	108	120		
485	Dibrommetacresol worn 312 hrs.	5	20	60	60	60	60	60	60	60	60	100	24	0
484	" worn 24 hrs.	5	100	..	..	..	..	..	..	..	..	..	0	..
488	" worn 48 hrs.	5	100	..	..	..	..	..	..	..	..	..	0	..
491	" worn 72 hrs.	5	100	..	..	..	..	..	..	..	..	..	0	..
492	" worn 96 hrs.	5	100	..	..	..	..	..	..	..	..	..	0	..
494	" worn 120 hrs.	5	100	..	..	..	..	..	..	..	..	..	0	..
498	" worn 168 hrs.	5	20	40	100	..	..	..	..	..	..	..	0	..
502	" worn 192 hrs.	5	100	..	..	..	..	..	..	..	..	..	0	..
505	" worn 216 hrs.	5	80	100	..	..	..	..	..	..	..	..	0	..
511	" worn 240 hrs.	5	100	..	..	..	..	..	..	..	..	..	0	..
514	" worn 264 hrs.	5	0	60	100	..	..	..	..	..	..	..	0	..
519	" worn 288 hrs.	5	40	60	100	..	..	..	..	..	..	..	0	..
521	" worn 312 hrs.	5	0	0	10	40	40	40	40	80	80	80	0	..
453	Tribrommetacresol worn 36 hrs.	5	80	100	..	..	..	..	..	..	..	..	0	..
455	" worn 72 hrs.	5	0	0	0	0	0	0	0	0	0	0	23	34
500	Monochlormonobrommetacresol worn 24 hrs.	5	20	80	100	..	..	..	..	..	..	..	0	..
503	" worn 48 hrs.	5	0	20	20	40	40	40	40	40	40	40	11	0
506	" worn 72 hrs.	5	0	0	0	0	0	20	20	40	40	40	58	50
518	Monochlordibrommetacresol worn 24 hrs.	5	40	60	100	..	..	..	..	..	..	..	0	..
533	" worn 48 hrs.	5	100	..	..	..	..	..	..	..	..	..	0	..
536	" worn 120 hrs.	5	0	20	60	100	..	..	..	..	..	..	0	..
534	Dichlormonobrommetacresol worn 48 hrs.	5	100	..	..	..	..	..	..	..	..	..	0	..
537	" worn 120 hrs.	5	100	..	..	..	..	..	..	..	..	..	0	..
539	" worn 144 hrs.	5	100	..	..	..	..	..	..	..	..	..	0	..
545	" worn 192 hrs.	5	100	..	..	..	..	..	..	..	..	..	0	..
551	" worn 240 hrs.	5	80	80	100	..	..	..	..	..	..	..	0	..
552	" worn 264 hrs.	5	20	40	100	..	..	..	..	..	..	..	0	..
553	Dichlormonobrommetacresol worn 288 hrs.	5	100	..	..	..	..	..	..	..	..	..	0	..
555	" worn 312 hrs.	5	80	100	..	..	..	..	..	..	..	..	0	..
560	" worn 336 hrs.	5	60	60	80	80	100	..	..	..	..	..	0	..
561	" worn 360 hrs.	5	20	60	80	100	..	..	..	..	..	..	0	..

TABLE XVI—*Continued*

IMPREGNATION WITH HALOGENATED CRESOLS

No.	Chemical	Total	Percentage dead in hours									Total eggs	Per cent hatched
			12	24	36	48	60	72	84	96	108	120		
523	Dibromtricresol with paraffine worn 96 hrs.	5	80	100	..	..	..	..	..	..	..	..	0	..
525	" " " worn 144 hrs.	5	40	100	..	..	..	..	..	..	..	..	0	..
527	" " " worn 168 hrs.	5	20	20	60	60	100	..	..	..	..	..	0	..
529	" " " worn 216 hrs.	5	0	0	0	40	40	40	80	80	100	..	Immature	
524	Dibromtricresol without paraffine worn 96 hrs.	5	100	..	..	..	..	..	..	..	..	..	0	..
526	" " " worn 144 hrs.	5	40	100	..	..	..	..	..	..	..	..	0	..
528	" " " worn 168 hrs.	5	40	80	100	..	..	..	..	..	..	..	0	..
530	" " " worn 216 hrs.	5	0	20	20	20	20	20	20	20	60	60	Immature	
531	Dibromcreosote worn 48 hrs.	5	100	..	..	..	..	..	..	..	..	..	0	..
535	" worn 120 hrs.	5	40	100	..	..	..	..	..	..	..	..	0	..
538	" worn 144 hrs.	5	60	100	..	..	..	..	..	..	..	..	0	..
542	" worn 192 hrs.	5	60	80	80	80	80	100	..	..	..	..	0	..
546	" worn 216 hrs.	5	60	100	..	..	..	..	..	..	..	..	0	..
548	" worn 240 hrs.	5	100	..	..	..	..	..	..	..	..	..	0	..
540	Tribrominated cresol liquid portion without paraffine worn 24 hrs.	5	100	..	..	..	..	..	..	..	..	..	0	..
543	Tribrominated cresol liquid portion without paraffine worn 72 hrs	5	100	..	..	..	..	..	..	..	..	..	0	..
549	Tribrominated cresol liquid portion without paraffine worn 120 hrs	5	60	100	..	..	..	..	..	..	..	..	0	..
554	Tribrominated cresol liquid portion without paraffine worn 168 hrs	5	20	40	40	60	80	80	80	80	80	80	0	..
557	Tribrominated cresol liquid portion without paraffine worn 216 hrs	5	0	0	80	80	80	80	80	80	80	80	0	..
556	Tribrominated tricresol crystals without paraffine worn 24 hrs.	5	100	..	..	..	..	..	..	..	..	..	0	..
559	Tribrominated tricresol crystals without paraffine worn 48 hrs.	5	80	100	..	..	..	..	..	..	..	..	0	..
572	Tribrominated tricresol crystals without paraffine worn 120 hrs.	5	0	40	60	80	100	..	..	..	..	..	Immature	

TABLE XVI—*Continued*

IMPREGNATION WITH HALOGENATED CRESOLS

No.	Chemical	Total	Percentage dead in hours									Total eggs	Per cent hatched
			12	24	36	48	60	72	84	96	108	120		
544	Sodium salt of dibrominated tricresol 5 c.c. to 100 c.c. of sodium hydroxide 17.77 grams of solution taken up worn 48 hrs.	5	100	..	..	..	..	..	..	..	..	..	0	..
550	Sodium salt of dibrominated tricresol 5 c.c. to 100 c.c. of sodium hydroxide 17.77 grams of solution taken up worn 96 hrs.	5	100	..	..	..	..	..	..	..	..	..	0	..
558	Sodium salt of dibrominated tricresol 5 c.c. to 100 c.c. of sodium hydroxide 17.77 grams of solution taken up worn 192 hrs.	5	80	100	..	..	..	..	..	..	..	..	0	..
571	Sodium salt of dibrominated tricresol 5 c.c. to 100 c.c. of sodium hydroxide 17.77 grams of solution taken up worn 264 hrs.	5	60	60	100	..	...	..	..	..	..	..	0	..
577	Sodium salt of dibrominated tricresol 5 c.c. to 100 c.c. of sodium hydroxide 17.77 grams of solution taken up worn 312 hrs.	5	40	80	100	..	..	..	..	..	..	..	0	..
581	Sodium salt of dibrominated tricresol 5 c.c. to 100 c.c. of sodium hydroxide 17.77 grams of solution taken up worn 336 hrs.	5	40	100	..	..	..	..	..	..	..	..	0	..
582	Sodium salt of dibrominated tricresol 5 c.c. to 100 c.c. of sodium hydroxide 17.77 grams of solution taken up worn 360 hrs.	5	40	80	100	..	..	..	..	..	..	..	0	..
584	Sodium salt of dibrominated tricresol 5 c.c. to 100 c.c. of sodium hydroxide 17.77 grams of solution taken up worn 384 hrs.	5	0	20	60	100	..	..	..	..	..	..	0	..
547	Dibrominated naphthalene without paraffine worn 48 hrs.	5	20	20	80	80	100	..	..	..	..	..	0	..
570	Monobromnaphthalene without paraffine worn 48 hrs.	5	100	..	..	..	..	..	..	..	..	..	0	..
574	" " " worn 72 hrs.	5	100	..	..	..	..	..	..	..	..	..	0	..
578	" " " worn 96 hrs.	5	100	..	..	..	..	..	..	..	..	..	0	..
580	" " " worn 120 hrs.	5	40	40	100	..	..	..	..	..	..	..	0	..
583	" " " worn 144 hrs.	5	0	0	0	0	0	..	..	..	..	..	0	..

In these experiments, 1 gram of the chemical was used to impregnate 48 sq. inches of the cloth and 3 grams of paraffine m.p. 51° C. were added except where mentioned.

Upon the advice of Dean John R. Allen, of the College of Engineering of the University of Minnesota, the apparatus described below was constructed and proved satisfactory. (Figure 2.) A chimney of galvanized iron 2.8 meters long and 46 cm. in diameter was constructed, and an oblong door 35 cm. in length was cut in 96 cm. from one end. This door was closed with a latch and the apertures along its edges were sealed with a mixture of beeswax, paraffine, and vaseline to avoid the entrance of air. Across the central axis of the chimney just below this door were soldered three horizontal iron rods, and on these were laid a platform of stout wire mesh. It was upon this platform that the samples for evaporation were laid. A 12-inch electric fan was now placed within the chimney about 40 cm. from the end nearest the wire platform. It was placed exactly in the mid-axis of the chimney, facing away from the latter and at right angles to its long axis, so that when turned on, the stream of air was sucked, not driven, across the surfaces for evaporation. Tests made with tobacco smoke introduced at the further end of the chimney showed that the currents of air twist somewhat along the outer 2 inches of the chimney, but the currents down the greater part of the lumen were practically uniform and parallel to the long axis of the chimney. Uniform evaporation might, therefore, be expected from surfaces exposed anywhere, except at the extreme outer portions of the chimney's lumen. As will be seen, this expectation was well borne out by the experimental test.

It was found, however, that when squares of woolen cloth were used, the change in weight of the square, when cut from the same piece of goods, was far from being uniform, and that changes in the humidity of the air from hour to hour were followed by great and irregular changes in the weight of the squares. These variations were too large to permit the cresol evaporation from the cloth to be studied by simple weighing.

Accordingly, the substances were placed in the lid of small weighed Petri dishes, 7 cm. in diameter, enough substance being used just to cover the entire surface of the dish. In the case of crystalline compounds, these were first melted in a tube and then dropped upon the slightly heated dish, spread evenly while still in liquid form and then allowed to crystallize. In this way they also covered the entire surface of the dish, presenting the nearest approximation to a uniform surface (38.5 square centimeters) that was possible. In the case of the dibrommono-chlormetacresol, the melting point was so high that it was found more convenient first to dissolve the substance in ether and then to transfer the solution to the Petri dish and evaporate off the ether.

The dishes were then weighed and placed on the platform in the iron chimney, distributed symmetrically on both sides of the midline. The fan was then turned on and air sucked through the chimney for periods of half an hour, after which the dishes were weighed again and the loss of weight

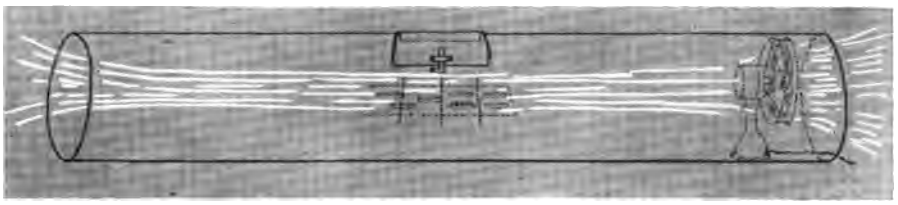


Figure 2

Sketch of apparatus used in the study of the volatility of different chemicals

determined. The loss of weight was quite as uniform as could be expected, the uniformity in the average changes being especially so. The rate of evaporation of the chemical shows a general conformity to the duration of its pediculicide action. (Table XVII.)

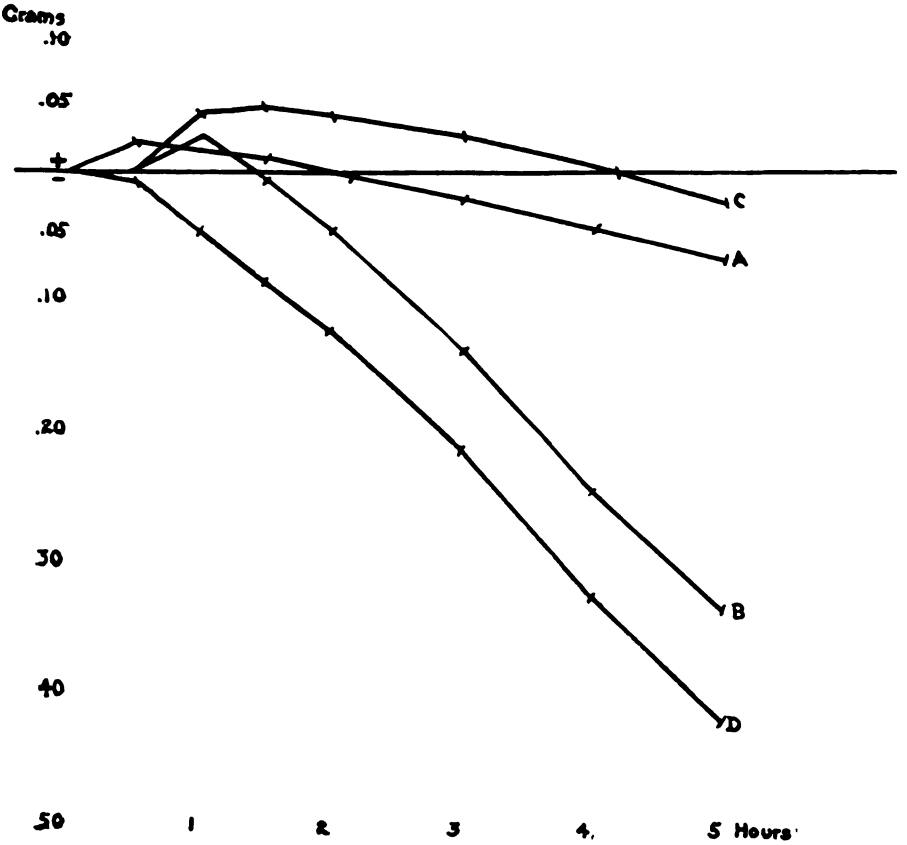
TABLE XVII

EVAPORATION PER HALF HOUR OF FANNING AT 72°–75° F. IN PETRI DISH 7 CM. IN DIAMETER (ABOUT 38.5 SQ. CM. SURFACE EXPOSED)

	Milligrams	Cresol coefficient. Mg. substance evaporating / Mg. cresol evaporating	Molecular cresol coefficient. Gram molecules substance / Gram molecules cresol
Metacresol	38.5	1.	1.
Monobrommetacresol	6.8	0.177	0.102
Dibrommetacresol	5.8	0.15	0.0609
Tribrommetacresol	0.3	0.008	0.0024
Dibrommonochlormetacresol	0.4	0.010	0.0036
Dichlormonobrommetacresol	0.5	0.013	0.0055
Crude cresol treated with 2 Br_2 liquid portion	0.9	0.0234	.....
Crude cresol treated with 2 Br_2 crystal portion	0.45	0.011	.....

Relationship to volatility, molecular weight, and toxicity to pediculicidal action.—Later experiments with the evaporation apparatus were carried out in a different laboratory, using a different fan, and were conducted at a different temperature; hence they can not be compared directly with those previously given. The Petri dishes used were uniform in size, giving a surface of 40.5 sq. cm. The temperature of the room was 25°–26° C. and the relative humidity varied between 50 to 65 per cent. The fan revolved at such a rate that a puff of tobacco smoke was carried the full length of the apparatus in 5 seconds, determined by a stop watch. A piece of sheet rubber packing was fastened on one side with adhesive tape and fitted under the door. By closing and clapping the door over this packing, all penetration of air along the edges of the door was prevented without the use of the mixture of beeswax, paraffine, and vaseline used previously. A glass plate was substituted for the wire netting, thus furnishing a more level surface for the Petri dishes. Loss of weight due to evaporation or gain in weight due to the absorption of water during weighing was prevented by weighing the dishes with their covers in place. The evaporation of compounds such as benzene was found to be retarded, due to the cooling effect produced by the rapid evaporation. By using a larger quantity of the chemical, 15 c.c. to 25 c.c., and running for periods of one half to one minute timed with a stop watch, this was overcome to a large extent. Less volatile chemicals were run for 15 to 30 minutes and in some cases for several hours between weighings. The first weighings usually did not represent the true loss by evaporation, since many of the chemicals first took up water, often so large an amount that an increase in weight resulted.

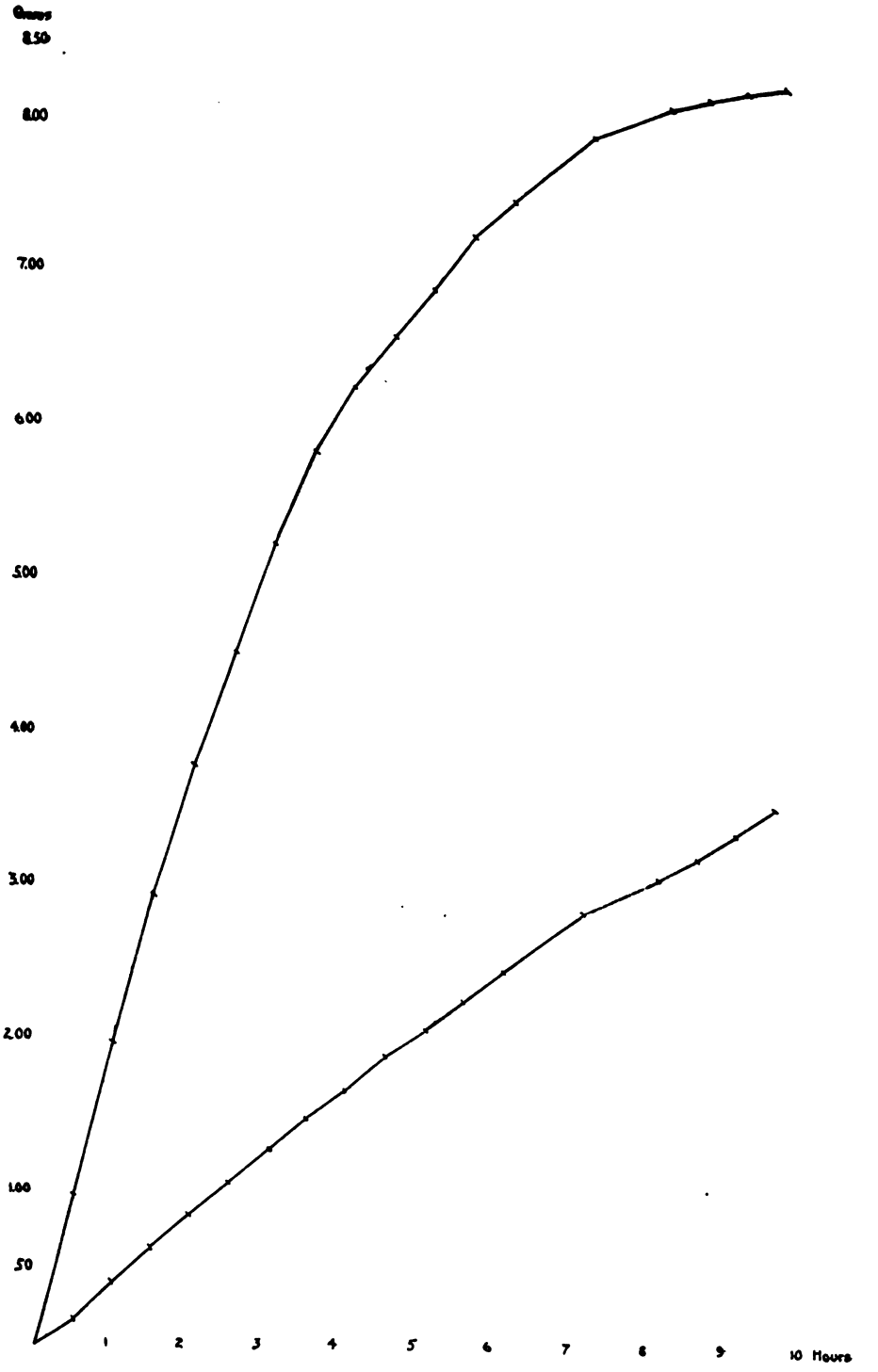
Curve 5 shows such an increase and also a comparison of the rate of absorption and rate of evaporation between dishes exposed inside and outside of the evaporation apparatus. The rate at which sulphuric acid will take up water in such an air current as compared with the still air is given in Curve 6. Impurities more volatile than the chemical to be tested were another source of error in the first weighings, hence only those weighings obtained after the loss had become uniform were accepted as representing the rate of evaporation of the chemical.



Curve 5

Showing gain and loss in weight of 2 grams (A and D) and 5 grams (B and C) of meta-cresol exposed in the evaporation apparatus (B and D) and outside the apparatus (A and C). Temperature 22°–24° C., relative humidity 55 per cent

Considering the possible substitutions in the benzene ring, the aldehydes are, as a rule, too unstable to give good results as pediculicides; while the amino and nitro groups are too toxic for the purpose. Only one hydroxyl group may be used since two hydroxyls reduce the volatility to such an extent as to make the chemical ineffective. Iodine is not abundant



Curve 6

Showing the increase in weight due to the absorption of water by 9. 2 grams of sulphuric acid exposed in the evaporating apparatus (upper curve) and outside apparatus (lower curve). Temperature 22°–24°C., relative humidity 55–60 per cent

enough to be used on so large a scale. There is left the methyl and similar groups, together with chlorine or bromine, as possible groups to be used to reduce the volatility. One hydroxyl group will furnish the desired toxicity to the chemical. Table XVIII gives the results of a study of possible compounds. When tribrommetacresol failed to kill it was thought to be due to its low volatility, but further study shows that even compounds much lower in volatility will kill quickly providing they have a high toxicity. Molecular weight or the size of the molecule appears to

TABLE XVIII

SHOWING IN GRAMS THE QUANTITY OF EACH CHEMICAL EVAPORATED FROM 1 SQ. IN. PER ½ HR. AT TEMPERATURE 76°–78° F.

Chemical	Grams per 1 sq. cm. per ½ hr.	Mol. weight	Time required to kill lice
Benzene	1.0339	.....	.....
Toluene	.2968	.....	.....
Xylene	.09815	.....	.....
Monobrombenzene	.08592	.....	.....
Monoiodobenzene	.0237	.....	.....
Benzaldehyde	.01214	.....	.....
Paradichlorbenzene	.010483	.....	.....
Benzyl alcohol	.0048086	.....	.....
Anilin	.00457	.....	.....
Mononitrobenzene	.003061	.....	.....
Orthocresol	.002987	.....	.....
Phenol	.002185	.....	.....
Paracresol methylether	.0016814	.....	.....
Orthocresol methylether	.0016148	.....	.....
Metacresol	.0013407	.....	.....
Tricresol–35 per cent ortho, 40 per cent meta, 25 per cent para	.0012479	.....	.....
Metacresol	.001180	.....	.....
Paradibrombenzene	.001120	.....	.....
Paracresol	.000881	.....	.....
Monobrommetacresol	.0008617	.....	within 12 hrs.
Naphthalene	.0008609	128.1	within 12 hrs.
Xylenol	.000824	122.	within 12 hrs.
Monochlororthocresol	.000800	142.46	within 12 hrs.
Monobromnaphthalene	.0007654	206.92	within 12 hrs.
Parachlorphenol	.000707	128.46	.....
Monobromxylenol	.000679	200.92	within 12 hrs.
Monoiodoorthocresol	.000572	233.92	within 12 hrs.
Dibrommetacresol	.000560	265.84	within 12 hrs.
Carvacrol	.00034	149	within 12 hrs.
Dibromtricresol	.000271	265.84	within 12 hrs.
Dibromxylenol	.000237	279.84	within 12 hrs.
Eugenol	.000171	164	within 12 hrs.
Tribromphenol	.0001673	330.76	within 60 hrs.
Monobromcarvacrol	.000142	227.92	within 12 hrs.
Tribrommetacresol	.0001	344.76	not killed
Heliotropine	.0000905	150.1	within 12 hrs.
Dibromnaphthalene	.0000781	285.84	within 60 hrs.
Dibromeugenol	.0000360	323.94	within 20 hrs.
Metadinitrobenzene	.0000074	168	within 12 hrs.
Alphanaphthol	.00000567	144	within 72 hrs.
Resorcinol*	.00000000	110	not killed
Paranitrophenol*	.0000000	139.01	not killed
Orcinol*	.0000000	110	not killed

* Probably oxidized since a slight increase in weight was noted.

have some bearing on the question. Whether the size of the molecule influences the penetration through the chitin, or whether the weight of the molecule influences the results by slowing down the rate of diffusion of the vapor, is not known. On the other hand, the bromine may act by reducing the toxicity of the chemical, since dibromeugenol, where the bromine is on the side chain, does not influence the toxicity as much as tribromphenol, tribrommetacresol, or dibromnaphthalene, where the bromine was introduced in the benzene ring.

Turning to the practical application of these data, it was found that the best of the less volatile compounds, dinitrobenzene, could not be used because of its high toxicity. Heliotropine tends to crystallize and is rubbed off the underwear by friction, while monobromcarvacrol disappeared from the underwear in ten days' time. Dibrommetacresol and the monobromdichlormetacresol was worn in warm weather under a B. V. D. suit of underwear and lasted 13 days, while monobromcarvacrol was worn in the cool autumn weather under a suit of gauze underwear. The rapid disappearance of the monobromcarvacrol can not be explained on the basis of volatility since it is only about one fifth as volatile as the dibrommetacresol; hence it must either be due to a more rapid absorption by the skin or to absorption in the surrounding clothing. If the latter view is correct, which appears probable, a field trial where the entire clothing would be treated should give better results with monobromcarvacrol than with dibrommetacresol. As far as our own tests upon pieces of cloth have actually demonstrated, however, the most lasting results have been obtained (in order of efficacy) with the sodium salt of the dibrominated crude cresol, the monobromdichlormetacresol, and the dibrommetacresol. A field study of these chemicals has not been possible, due to the signing of the armistice. All that can be stated concerning their value is that, under laboratory conditions, they give better results than are obtained in experiments with preparations already tested in the field; hence it is reasonable to hope that they would also prove superior under field conditions.

SUMMARY

The entire investigation may be briefly summarized as follows:

1. Lice may be reared under incubator conditions in large numbers, if fed with human blood twice daily, but under such conditions the life cycle is slowed down, and the daily and total egg production per female is reduced.

2. Fever, rash, and a general lassitude are produced as a result of the louse bites.

3. Lice and their eggs are destroyed by the ordinary laundering processes used in the washing of cotton and khaki goods; for woolens slight alterations in the methods of washing are necessary.

4. Chlorpicrin may be used for fumigation of garments, accomplishing the desired results in a short period of time, with a small quantity of the chemical, without the use of high temperatures.

5. The sachet method of controlling lice is ineffective or very expensive.

6. Louse powders may be used with success but, being a wasteful method of applying an insecticide, are not recommended.

7. Impregnation of the underwear is the most promising method of louse control between lousings. Active chemicals of very low volatility are necessary to prove effective for the longest period of time. Halogenated phenols such as dibrommetacresol, dichlormonobrommetacresol, and their sodium salts, dibromcarvacrol, and dibromxylenol were found to be the most promising under laboratory conditions.

APPENDIX

APPENDIX

THE PREPARATION OF CERTAIN OF THE COMPOUNDS USED IN THE EXPERIMENTS

Since this research was undertaken with the purely utilitarian purpose of obtaining substances best suited for the killing of lice, this aim, rather than that of detailed chemical study, has remained paramount. Some of these substances such as dibrommetacresol, monobromdichlormetacresol, and dibrommonochlormetacresol are not described in Beilstein's *Handbuch der organischen Chemie*, Richter's *Lexikon der Kohlenstoff-Verbindungen*, nor Aberhalden's *Biochemisches Handlexikon*, nor in any of the articles of the literature consulted.

Brominated cresols.—Brominated cresols were prepared from stock samples (Kahlbaum) of orthometa and paracresol in two ways. First, the bromine was introduced into the benzene ring by the method which Koppeschaar described for the quantitative determination of cresol, using a mixture of sodium bromide 5/10 grm. mol. (=51.5 grm.) plus, sodium bromate 1/10 grm. mol. (=15.1 grm.) per liter. According to formula

$$5\,NaBr + NaBrO_3 + 6\,CH_3COOH = 3\,Br_2 + 6\,CH_3COONa + 3\,H_2O$$

1/10 grm. mol. of the cresol (10.8 grm. = 10.5 c.c. at 25°) or a proportionate amount, was first dissolved by adding sodium hydroxide solution, and the necessary amount of brominating solution, followed by sufficient glacial acetic acid to insure an excess, to bring about the desired one of the following reactions:

(1) $CH_3C_6H_4OH + Br_2 = CH_3C_6H_3BrOH + HBr$

(2) $CH_3C_6H_4OH + 2Br_2 = CH_3C_6H_3Br_2OH + 2HBr$

(3) For metacresol only

$CH_3C_6H_4OH + 3Br_2 = CH_3C_6HBr_3OH + 3HBr$

The mixture was always shaken in a mechanical shaker and allowed to stand from a few minutes to an hour until the reaction was complete. Completeness of the reaction was always tested by taking a small aliquot portion of the supernatant liquid as a sample adding 1-2 grm. KI, diluting with 20 c.c. H_2O and allowing to stand in the dark for 20 minutes, after which a little starch solution was added and the excess of iodine was titrated with n/10 sodium thiosulphate. Tho there was usually a trace of iodine liberated, the brominating reaction was usually practically complete within a few minutes.

The second method and the one which was used in making most of the bromine compounds was suggested by Professor W. H. Hunter of the School of Chemistry of the University of Minnesota. The cresol was dissolved in glacial acetic acid (200 to 500 c.c. per gram molecule used) in an Erlenmeyer flask, and a bit of fine bright iron wire was introduced as a catalyzer. The required amount of bromine (Br = 80, sp. gr. 2.99; $Br_2 = 160/3 = 53.3$ c.c.) was then measured out into a separatory funnel and allowed to drip slowly into the Erlenmeyer flask containing the cresol and acetic acid. Where relatively large amounts of bromine were used, the flask was placed in an iced bath. The reaction, as tested by the amount of iodine liberated on addition of KI to a sample, was found to be almost quantitative at the end of one hour.

The glacial acetic acid was then diluted with ten or twenty volumes of water, and shaken in a mechanical shaker for five minutes, after which it was allowed to stand for a few minutes, during which time the heavy brominated cresol settled to the bottom. The greater part of the supernatant liquid was then decanted off. When the brominated cresol was a solid, it was filtered off on a Buchner funnel; when a liquid, it was removed by means of a separatory funnel. In either case, the

excess of halogen was removed by shaking with an excess of 5 or 10 per cent sodium, thiosulphate, and allowing it to stand about an hour. This procedure removed not only the free bromine, but also liberated any bromine which might have replaced the hydrogen in the hydroxyl group of the cresol, for Ditz and Cedivoda have shown that when more than the equivalent of 2 Br_2 is added to ortho- or paracresol, or when more than 3 Br_2 is added to metacresol, such products are formed. When the proper amounts of bromine to exactly conform to the reactions (1), (2), and (3) above mentioned have been added, no appreciable amounts of these OBr compounds are formed.

After the substance was digested with sodium thiosulphate, the supernatant liquid was removed and the brominated cresol was shaken with dilute sodium bicarbonate solution until the supernatant liquid remained just alkaline to phenolsulphonphthalein. The chemical was then repeatedly washed by shaking with distilled water. The end product was finally separated from the water in a funnel or by filtration.

Chlorine was introduced into the benzene ring in the same general way, by dissolving the cresol in a counterpoised flask containing the cresol dissolved in glacial acetic acid cooled in an ice bath, and then passing in dry chlorine gas until the desired gain in weight was attained. As in the case of bromine, a bit of iron wire was used as the catalyzer. The chlorine was generated in the usual way by dropping concentrated hydrochloric acid from a separating funnel into a flask containing manganese dioxide. The flask was immersed in a boiling water bath. The chlorine was washed and dried by passage through water and concentrated sulphuric acid.

Excess of chlorine was tested for in the same manner as excess of bromine. The reaction, however, was complete, as in the case of bromine.

The dibrommonochlormetacresol was prepared from the dibrommetacresol by dissolving 28.6 grm. (1/10 grm. molecule) of the latter in glacial acetic acid, adding a little bright iron wire, and then placing the flask in an ice bath and passing in dry chlorine until the flask gained 7.1 grm. in weight ($=Cl_2$). After an hour's standing, a sample was tested with KI and thiosulphate and the reaction was found to be practically complete. The product was then prepared and purified in the same way as the other halogen derivatives.

The monobromdichlormetacresol was prepared from monobrommetacresol, by passing in 14.2 grm. ($=2\ Cl_2$) instead of 7.1 gram chlorine.

Iodine was found to enter the benzol ring of cresol somewhat less readily than chlorine or bromine. It was therefore introduced in an alkaline medium by the method described by Redman, Weith, and Brock, for the quantitative estimation of cresols. In one liter of normal (84 grm.) sodium bicarbonate 10.3 c.c. of cresol were dissolved and into this was poured (23.4 grm. = 1/10 gram molecules or multiples thereof) iodine which had been dissolved in 10 per cent KI solution. The mixture was shaken, acidified with acetic acid, digested, and finally washed in the manner described for the chlor and brom derivatives.

The iodo cresols were tarry masses with a sticky consistency and a very disagreeable odor, which facts considered with their lower killing power and much greater expense, render them less desirable for use as pediculicides.

After a considerable degree of success had been attained with the above mentioned halogenated metacresols, an attempt was made to brominate the crude cresols. When quantities equivalent to 2 Br_2 per molecule cresol were added to crude tricresol, the reaction proceeded quantitatively with the usual rapidity and a thick, syrupy liquid containing some small crystals was obtained. For purposes of brevity this was designated as "dibrominated tricresol," tho it was recognized that it was a mixture, and in all probability contained some monobromcresols and some tribrommetacresol. However, after the usual digestion with thiosulphate used in the process

of purification, there were certainly no -OBr compounds present in the substance when tested on the lice.

A similar preparation designated as "tribrominated tricresol" was also made using an equivalent of 3 Br_2 per molecule of tricresol. This contained a definite excess of Br_2 at the end of the hour, about equal to 1 Br. If, as is frequently the case, about 40 per cent of the tricresol is in the form of meta cresol, this would correspond very well to a yield of all the metacresol in the form of the tribrom compound and all the ortho and para in the form of dibrom substitution products.

In the course of bromination, a mass of beautiful needle-shaped crystals separated from the glacial acetic acid and was removed on a Buchner funnel. This, when purified, was designated as "tribrominated tricresol crystals" and the substance derived from the filtrate was, after purification, designated as "tribrominated tricresol liquid" altho, as a matter of fact, it probably represented chiefly dibrominated compounds (ortho- and paracresol). It crystallized into a homogeneous chocolate-like mass after standing several days.

Tested in the evaporation apparatus, the "crystal" fraction showed 0.45 mg. evaporation and the "liquid" fraction 0.9 mg. per half hour.

Separation of metacresol from ortho- and paracresol in crude cresol.—Since metacresol now on the market is quite expensive, it seems possible that this might be cheaply prepared for the purposes of this work by the method which has been described by P. Riehem. Riehem adds barium hydroxide solution to the crude cresol and concentrates the mixture. All the other salts crystallize before the barium metacresylate which remains in the mother liquor. This can then be freed from barium by the addition of mineral acids which causes the cresol to separate. The original ortho- and paracresol and all the barium used can, of course, be regained quantitatively.

Salts of cresols.—The compounds formed by cresols with various hydroxides were briefly studied. The sodium cresylates are sufficiently well known to require no further description. The sodium salts of dibrommetacresol and monobromdichlormetacresol were prepared by one of us by adding 3 per cent NaOH to an excess of the substance and allowing the mixture to stand upon which the excess settled out. This method seems at present to afford the greatest promise of all and warrants further investigation. The only drawback in practice seems to be the readiness with which sodium cresylate is soluble in water.

Upon standing or heating with calcium hydroxide, either solution or solid, calcium cresylates were readily formed. These calcium cresylates are somewhat less water-soluble than the sodium salts, and should therefore prove more useful.

The barium compounds are also readily prepared, but on account of the great toxicity of barium they could not be used in this work.

The aluminum cresylates have been described by Gladstone and Tribe. They are readily formed when the corresponding cresol is heated to its boiling point with aluminum under a reflux condenser in the presence of a small quantity of iodine. The reaction then proceeds with great violence, and in our experiments this was so great that several condensers and flasks were destroyed. By adding the cresol in relatively small fractions (not more than 50 c.c. at a time), however, no difficulty was encountered. The aluminum cresylates as described by Gladstone and Tribe are very unstable and break up at once upon contact with the air, to yield aluminum hydroxide and cresol.

Magnesium hydroxide readily forms a water-soluble cresylate with cresols, similar to the calcium cresylate.

Much might be hoped from a zinc compound, should it have properties somewhere midway between those of the magnesium and aluminum salts. Neither metal-

lic zinc nor zinc oxide, however, yielded a well-defined, soluble or insoluble zinc cresylate, nor was one readily obtained by the addition of zinc chloride to aqueous solution of sodium cresylate. It is possible that such a compound may be prepared by the action of zinc chloride upon dry sodium cresylate and if so, that its homologues made from sodium dibrommetacresylate or sodium monobromdichlormetacresylate might prove more useful than any of the substances studied.

Ferric hydroxide and ferric chloride in the presence of cresol dissolved in sodium hydroxide solution also failed to yield well-defined cresylates.

DESCRIPTION OF THE HALOGENATED CRESOLS

Monochlororthocresol.....light tan to orange colored; colored needle-like crystals
Monobromorthocresol.....brown liquid
Monochlormonobromorthocresol.....light orange, short and rather thick needle-like crystals
Dibromorthocresol.....white needle-like crystals, gradually turning to tan color on standing in closed flask. m.p. 66°–68°
Monoiodoorthocresol.....dark reddish brown liquid
Diiodoorthocresol.....
Monobrommetacresol.....light brown liquid, rather difficult to crystallize, even in freezing mixture. When crystalline, it forms white to orange needle-like crystals. Avr. evaporation per half hour ventilation 6.8 mg.
Dibrommetacresol.....white to light brown silky crystals. Average evaporation per half hour ventilation[a] 5.8 mg. m.p. 70°
Dibrommonochlormetacresol.....white needle-like crystals, gradually turning to light tan. Average evaporation per half hour 0.4 mg.
Monobromdichlormetacresol.....fine white needles; average evaporation per half hour 0.5 mg. m.p. 62°
Tribrommetacresol.....white to orange-yellow needles; average evaporation per half hour 0.3 mg.
Monobromparacresol.....light brown liquid

Preparation of other chemicals.—Among these may be mentioned cresyl benzoate, methylene dicresol, monocresyl phosphate and tricresyl phosphate, and a liquid distilled from aluminum cresylate at a temperature above 273°. This liquid had a pleasant odor resembling geraniums. It has been described by Gladstone and Tribe as containing both cresyl ether and cresyl ketone. In spite of its high boiling point and the fact that it at first killed lice, it soon lost this power, which originally may have been due not to the ether or the ketone, but to impurities remaining in the substance. It was not studied further.

A mixture of di and tetrachlor naphthalene was prepared by the method of Emil Fischer (mixing napthalene with powdered $KClO_3$ and dropping balls of the mixture into concentrated HCl). This also failed to give further promise, as did also the mono- and dibromnaphthalene prepared by the action of Br_2 and 2 Br_2 respectively upon naphthalene in glacial acetic acid. Neither of these compounds was nearly as satisfactory as the corresponding compounds of cresol, and the higher bromine compounds were therefore not prepared.

At an early stage of this work, dinaphthylmethane $CH_2\begin{matrix}/C_{10}H_7\\\backslash C_{10}H_7\end{matrix}$ was prepared by the method of Grabowski (by the action of 1 part methylal on 5 parts of naphthalene in chloroform to which 5.5 c.c. concentrated sulphuric acid was gradually added). This substance also was not suited for the louse-killing.

Attempts to produce pediculicide substances by the action of sulphur upon naphthalene and by the action of sulphur upon hexemethylene tetramine, as well as upon ammonia and formaldehyde in alkaline solution yielded nothing which gave any promise.

[a] 72°–75° F. Evaporation tested in apparatus described. Evaporation of metacresol per half hour = 38.5 mg.

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